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Note: To report additional accounting and appropriations data use EPA Form 1900-69A.										
SFO (Max 2) <input type="checkbox"/>										
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Authorized Work Assignment Ceiling										
Contract Period:		Cost/Fee:				LOE:				
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Work Plan / Cost Estimate Approvals										
Contractor WP Dated:		Cost/Fee:				LOE:				
Cumulative Approved:		Cost/Fee:				LOE:				
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**PERFORMANCE WORK STATEMENT
CONTRACT EP-C-12-021
WORK ASSIGNMENT 0-41**

TITLE: Systems-Based Sustainability and Emerging Risks Performance Assessment of Cincinnati Regional Water Technology Innovations: Comparative Life Cycle Assessment and Cost Analysis of Water Treatment Options

PERIOD OF PERFORMANCE: December 19, 2012 through September 25, 2013

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1. BACKGROUND

1.1. Cincinnati Regional Water Technology Innovation Cluster

The Water Technology Innovation Cluster (WTIC) initiated in Dayton/Cincinnati/northern Kentucky/southeast Indiana was formed in January 2011 to develop and commercialize innovative water technologies that solve environmental challenges and spur sustainable economic development in the region. The WTIC builds on existing firms, intellectual capacity, and expertise in the region that can be used to advance economic development and technology innovation in a strategic and coordinated manner. This grassroots organization was developed by a coalition of private and public sector leaders from the region with assistance and inspiration from EPA and the U.S. Small Business Administration¹.

As one of the largest federal water research and development laboratories in the United States, EPA Cincinnati generates innovative solutions that protect human health and the environment

¹ Events leading up to the formation of the WTIC are available in the WTIC Background and Timeline.
http://www.epa.gov/nrmrl/watercluster/docs/WTIC_BG_Timeline.pdf

and present opportunities for private sector growth. The rich research, development and demonstration (RD&D) infrastructure provided by EPA Cincinnati and innovative researchers is a technical anchor for the WTIC and a national draw to the region.

The EPA cluster team coordinates joint activities (such as meetings, workshops, and test events) that support EPA and the WTIC's interest in RD&D for innovative water technologies that advance economic development and solve environmental challenges. As part of this role, the cluster team coordinates both internally (with EPA Cincinnati research staff) and externally (with the WTIC and technology vendors) to identify topics, capabilities, and EPA Cincinnati research leads and facilities for joint projects.

This project is made possible through support provided by the EPA cluster team. It provides a basis for evaluation of new technologies under development within the WTIC and will guide investment leading to the commercialization of innovative water technologies developed by companies within the Cincinnati region.

1.2. Technology Evaluation

This Statement of Work provides the model basis for evaluation of five technologies currently under development in connection with the Cincinnati Regional Water Technology Innovation Cluster or within the EPA's National Risk Management Research Laboratory. Each technology provides an alternative means of water disinfection. For each technology, there are associated differences in pathogen removal, disinfection by-product formation, source water residence times, treatment facility energy use and operating costs, chemical interactions with other species, supply chain impacts, and infrastructure requirements. The first four technologies will be evaluated in connection with drinking water disinfection while the fifth will be evaluated for use in wastewater disinfection. Two of the drinking water disinfection technologies utilize novel ways of applying UV light as the disinfecting agent and will be compared to conventional medium-pressure UV disinfection systems.

1.2.1. Ultraviolet light from LED and plasma lamps

Ultraviolet radiation can be used effectively to treat water for viruses and bacteria and could be used together with other processes to treat drinking water. Within the context of the Cincinnati WTIC, two technologies involving UV radiation are being developed. The first, relying on UV category C short wave radiation (UV-C) has recently been commercialized by Aquionics, Inc. located in Erlanger, Kentucky. The second is a plasma bead UV technology under development by Imaging Systems Technologies located in Toledo, Ohio. Because UV acts on the DNA of microorganisms, there is a relationship between its effectiveness and microorganism-size. UV disinfection has been investigated by the US EPA Environmental Technology Verification Program for DWT (<http://www.epa.gov/nrmrl/std/etv/vt-dws.html#uoidot>) and through initial LCA analysis.

1.2.2. Ferrate

Ferrate is currently being investigated as an oxidative technology with a range of treatment benefits including disinfection, enhanced coagulation, and adsorption for removal of arsenic, chromium, and trace organic contaminants. Several chemical delivery systems have been developed for ferrate including on-site production of a liquid source and production of the

chemical as a liquid or solid. Battelle has conducted significant internal research and development on ferrate and is currently exploring options for further development. The currently available commercial manufacturer of on-site ferrate production is Ferrate Treatment Technologies, Orlando FL, who we will work with to provide technical input.

1.2.3. Ultrafiltration

Ultrafiltration refers to disinfection with a filter capable of removing particles in the range 0.001 – 0.1 μm and is capable of removing biological as well as viral pathogens. Ultrafiltration has been investigated by researchers at the EPA's National Risk Management Research Laboratory in connection with point-of-use treatment units. This technology has been commercialized for full-scale water filtration plants, but its primary application in the US has been in connection with point-of-use devices in hospitals and care facilities where there is a heightened risk from exposure to pathogens.

1.2.4. Peracetic acid

Peracetic acid (PAA) is an emerging disinfectant for WWT systems, which has been used in clinical and other areas that require minimal by-product formation. Peracetic acid is of interest due to its potential as a means of reducing the presence of genotoxic substances in waters. However, the effectiveness of PPA in water matrices with differing disinfectant demand remains unclear.

1.3. Approach

This statement of work involves establishing a model using a LCA framework and incorporating novel aspects relevant to understanding municipal water management. The Contractor Team shall include individuals with significant LCA experience. Understanding water systems requires expertise associated with water-related technologies and risk assessment related to waterborne pathogens and toxins. Individuals contributing these skills to this work are expected to possess a working knowledge of LCA and to be able to make connections between an LCA modeling framework and other, more narrowly focused assessments of technical feasibility, cost, and risk. Doing this requires not only a theoretical understanding of LCA, but an understanding relevant to the practical challenges associated with the data and tools typically used for LCA studies. A key feature of the successful execution of this work will be to carry out a number of activities focused on technical details tasks while maintaining the perspective of broader system and making decisions regarding where to focus efforts based on key features and differences in the systems being studied.

The ambitious set of tasks described here are intended to inform decision making through the provision of information in the form of quantitative results that encompass a broad range of considerations while maintaining scientific rigor. To achieve these goals efficiently, an EPA Technical Team consisting of experts in microbial assessment, water-related risk assessment, LCA, and sustainability analysis will interact with the Contractor to provide timely, pragmatic, and decisive responses to questions, which will inevitably arise regarding overcoming obstacles encountered in the course of the work. The EPA Technical Team will serve as liaisons between the Contractor and a network of experts within EPA and the Water Technology Innovation Cluster who can be called upon to provide necessary data such as technical details of water treatment technologies, appropriate values for key model parameters, and pragmatic approaches

to incorporating findings from prior risk assessments into the LCA framework. The Cincinnati Water Technology Innovation Cluster, EPA's Office of Research and Development, and EPA's Office of Water provide a very strong network of expertise that is expected to be drawn upon to inform and strengthen this work while expediting data collection and model development. Together with the network of other expert contacts accessible through the Contractor's team and the EPA Technical Team, the wide range of information needed to support this modeling effort can be efficiently collected. By leveraging a broad base of expertise, it is expected that this statement of work can be carried out at a rapid pace without unnecessarily compromising inclusiveness or rigor.

This models developed here are anticipated to serve as the basis for future assessments of water-related technologies and to be incorporated into broader, sustainable systems analysis studies of water systems. The EPA Technical Team is interested in engaging the Contractor to provide talented individuals who see career benefits associated with serving as authors of scientific publications and involvement in this potentially foundational work.

2. SCOPE OF WORK

2.1. Objective

This project has two objectives, to perform environmental and economic life cycle assessments (LCA) to evaluate the environmental outcomes and costs associated with four innovative water treatment technologies currently under development within the Cincinnati region and in the course of doing this to establish an LCA model framework that could be used to study other technologies or changes to municipal water management systems in the future. The information provided by this study will be used to guide investment in regional water technology innovations and to facilitate the commercialization of promising technologies. The models developed here will be incorporated in a broader effort to develop a framework for assessment of next-generation water technologies and/or infrastructure (re)development based on their performance as measured by the environmental, economic and societal considerations required to address water-systems' sustainability. In particular, this project will focus on evaluating technology options for drinking and wastewater disinfection, acknowledging implications for increasing the efficiency and effectiveness of control of a broad spectrum of waterborne contaminants and improved public health protection from toxins and pathogens that could lead to waterborne disease outbreaks.

2.2. Expected outcomes

To accomplish these objectives, this project aims to (1) develop a set of system descriptions for the relevant processes, (2) collect the secondary data necessary for augmenting existing models through literature review and engaging potential data providers, (3) develop economic accounts for drinking water treatment (DWT) and wastewater treatment (WWT) alternatives, (4) develop new LCA unit processes, (5) combine existing and new LCA unit processes into an LCA model for comparative analysis, (6) carry out a contribution analysis and sensitivity analysis using the model, and (7) document model development and results in the form of manuscripts intended for submission to peer-reviewed journals.

The product of this Statement of Work are system descriptions, unit process and economic datasets, LCA models, and incremental development of relevant performance metrics and sustainability indicators to assess emerging DWT and WWT options against conventional systems. The treatment alternatives under consideration include ferrate, alternative UV systems (LED & plasma bead), and peracetic acid. Accomplishing this will involve novel development of an LCA-based approach that incorporates both traditional and emerging water quality criteria as well as a quantitative and actionable sustainability analysis.

The study will be conducted with a focus on transparency and establishing an appropriate scientific basis for future assessments. As such, all relevant background information, methods, data sources and transformations, results, and discussion will be documented in a white paper format consistent with publication in a peer-reviewed scientific journal. The article format was chosen as the preferred approach to documenting this work because it provides a focused presentation of key contributions and findings of each Task. Additional documentation necessary for ensuring reproducibility of results will be provided in the form of Supplemental Information for each white paper. While EPA acknowledges that limited resources and factors out of the control of the parties involved in this agreement do not allow for contractual certainty regarding publication, it is intended the co-authored white papers developed through this Statement of Work will be further edited by the EPA Technical Team and published in peer-reviewed scientific journals. The LCA unit process and impact characterization data used within this project will be provided at their full resolution to EPA in MS Word and Excel files as well as in an OpenLCA database for public dissemination at EPA's discretion.

2.3. Life Cycle Assessment: Goal, Scope, and Functional Unit

Goal:

This Statement of Work includes comparison of DWT alternatives (Tasks 1-3) and waste water treatment alternatives (Tasks 4-5). While the specific goal of each task varies, the overarching goal is to provide a consistent basis for comparison of DWT and WWT alternatives across the suite of impact categories listed in Table 1. Separate life cycles are identified for drinking water and waste water. The broader context for this LCA study is that it is expected that it will provide a basis for follow on studies, which combine the LCA models developed here with additional system aspects to provide a more complete system-wide sustainability analysis for municipal and regional water systems.

Scope:

The scope for drinking water includes water acquisition, treatment, distribution, and use. The scope for wastewater includes sewage collection, treatment, waste management, and the return of treated wastewater to a river.

The scope includes using parameters within the unit processes developed here to track sources of variability deemed to have significant influence on the outcomes measured. For drinking water and wastewater disinfection, these include concentration-time requirements for chemical disinfectants and residence time requirements for UV systems. At the level of the whole DWT system, the effect of variability in source water characteristics will be considered. At the level of the whole WWT system, the effect of wastewater characteristics, wastewater flow rate, and

temperature will be considered. The specific characteristics of drinking water and wastewater are described below.

A novel aspect of this study is the attempt to quantitatively characterize the effect of differences in the levels of disinfection by-products and pathogens in drinking water on human health outcomes and to combine these effects with human health effects calculated using the USEtox model characterization factors for other life cycle stages. In addition to the typical mass balance considerations that are typically used to produce LCI unit processes, a distinct feature of this work is the Contractor shall maintain an account of certain characteristics of the water flowing through the drinking water and WWT systems. These characteristics are the ones, which will be used for the variability assessment previously described. The characteristics anticipated to be tracked in wastewater, source water and treated water are detailed below.

Microorganisms:

- *Cryptosporidium parvum/hominis*
- *Giardia lamblia*
- Heterotrophic plate count
- *Legionella* spp.
- Fecal coliform
- *E. coli*
- Enteroviruses
- Adenoviruses

Disinfection by-products (DBPs):

- Bromate
- Chlorite
- Total trihalomethanes (TTHM)
- Haloacetic acids (HAA5), defined as the sum of five key species, monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid.

Disinfectants:

- Chloramines
- Chlorine
- Chlorine dioxide

Other water characteristics:

- Dissolved solids⁴
- Suspended solids⁴
- Turbidity
- Dissolved organic carbon (DOC)
- Biochemical oxygen demand⁴ (BOD5), measured at 20°C over 5 days
- Total organic carbon (TOC)
- Temperature
- pH

Other chemicals considered:

- Nitrate
- Nitrite
- Ammonia
- Phosphorus
- Chromium
- Arsenic
- Iron²
- Other organic chemicals³
- Other inorganic chemicals³

These characteristics shall be tracked in a spreadsheet alongside the life cycle inventory unit processes and incorporated in unit processes using parameters to the extent feasible. During

² Most relevant for drinking water treatment source water.

³ Level of detail to be determined during the course of the study. Most likely this will be assessed qualitatively as a general category.

⁴ Most relevant for wastewater treatment source water.

development of unit processes related to drinking water, these characteristics shall be tracked from source water through DWT to use. In the second phase of the project, these characteristics shall be tracked from wastewater through WWT to release to the environment and then back into the previously developed DWT processes to assess the effect of differences in wastewater effluent on downstream use.

The impacts to be tracked are listed in Table 1. The TRACI 2.1 impact assessment method shall be the primary LCIA method with additional tracking of energy and water use and characterization of fossil and metal depletion based on ReCiPe and a custom method. In addition to these more traditional LCIA methods, three additional multi-attribute sustainability metrics will be calculated within the LCA model, Ecological footprint, emergy, and externality valuation. All of the LCIA methods used in this work have been primarily developed outside the scope of this project. While the scope of this project does not include significant LCIA development, characterization factors for a limited set of flows relevant for this work may need to be developed using the already defined approaches. This is most likely in the case of human health impacts. For example, in certain cases characterization factors for flows not included in the USEtox model results underlying TRACI 2.1 would be estimated by entering appropriate chemical characteristics into the USEtox spreadsheet model. Fossil and biogenic sources of carbon dioxide and methane emissions shall be distinguished in LCI unit processes. While both fossil and biogenic emissions will be assigned the same global warming potential, this distinction will be maintained for purposes of data presentation. Carbon uptake shall be accounted for as a negative emission within the inventory, however, this is not anticipated to be a significant feature of this work.

Table 1. Impacts and sustainability metrics tracked in this work.

Impact Category	Region	Methodology	Unit
<i>TRACI:</i>			
Acidification	Global	TRACI 2.1	H+ moles-eq.
Ecotoxicity	Global	TRACI 2.1	CTU
Eutrophication	Global	TRACI 2.1	kg N-eq
Global warming	Global	TRACI 2.1	kg CO ₂ -eq
HH criteria	Global	TRACI 2.1	PM ₁₀ -eq
HH toxicity - cancer	Global	TRACI 2.1	CTU
HH toxicity - non-cancer	Global	TRACI 2.1	CTU
Ozone depletion	Global	TRACI 2.1	kg CFC-11 eq
Smog	U.S.	TRACI 2.1	kg O ₃ -eq
<i>Resource use:</i>			
Cumulative energy demand	Global	Custom	MJ-eq
Fossil depletion	Global	ReCiPe	kg oil-eq
Metal depletion	Global	ReCiPe	kg Fe-eq
Phosphorus depletion	Global	Custom	kg P ₂ O ₅ -eq
Water depletion	Global	ReCiPe	m ³
<i>Multi-attribute sustainability metrics:</i>			
Ecological footprint	U.S.	Custom	gha
Emergy	Global	Custom	seJ
Externality valuation	U.S.	Custom	\$
<i>HH = human health; CTU = common toxicity unit; seJ = solar equivalent Joules; gha = global hectares</i>			

Functional unit:

The functional unit for drinking water is the use of a cubic meter of water, which meets or exceeds National Primary Drinking Water Regulations for microorganisms, disinfectants, disinfectant by-products, inorganics, organics, and radionuclides. The functional unit for WWT is the treatment of a cubic meter of wastewater to meet or exceed the National Pollutant Discharge Elimination System (NPDES) requirements for the Metropolitan Sewer District of Greater Cincinnati.

Overview and structure of the tasks

This Statement of Work is comprised of five tasks. The tasks relate to conventional and alternative technologies for drinking water supply and waste water management. More specifically the tasks are as follows:

- Task 1 – Life cycle assessment (LCA) and economic assessment of base-case municipal drinking water treatment** – *prepare overall project QAPP (see Section 4) then address (1) a base-case representative of Cincinnati, (2) a variation on the base case not including sorption, (3) a variation on the base case replacing chlorine with conventional UV as the disinfecting agent, and (4) a minimal treatment system without flocculation representative of a municipality with very high quality source water.*
- Task 2 – LCA and economic comparison of alternative disinfection technologies** – *including variations on the base-case municipal DWT system using (1) LED UV, (2) plasma bead UV, or (3) ferrate as the disinfectant.*
- Task 3 – LCA and economic assessment of point-of-use disinfection at hospitals and care facilities** – *consisting of municipal DWT with the addition of faucet level disinfection options: (1) granular activated carbon (GAC), (2) conventional UV & GAC, (3) ultrafiltration, (4) LED UV & GAC, and (5) plasma bead UV & GAC.*
- Task 4 – LCA and economic assessment of base-case wastewater management** – *including (1) a base case representative of Cincinnati and (2) a variation on the base case using conventional UV as the disinfecting agent.*
- Task 5 – LCA and economic comparison of base-case and peracetic acid wastewater treatment** – *including a variation on the base-case WWT system using peracetic acid as the disinfecting agent.*

While the order and timing of tasks are left for the Contractor to establish, certain aspects are planned such they build on one another. The tasks are set up such that each builds upon the modeling carried out in the previous tasks. Each task has been subdivided into the following subtasks describing the steps to efficient completion.

- Subtask 1 – Develop a set of agreed upon system descriptions*
- Subtask 2 – Data collection and unit process development: collect and process data from datasets, literature review, secondary sources, and through identifying and engaging relevant partners to produce life cycle inventory unit process datasets for use in modeling*
- Subtask 3 – Collect and process economic data*
- Subtask 4 – Incorporate unit processes and perform a reference set of model runs for base case*
- Subtask 5 – Sensitivity analysis and optional additional uncertainty analysis*
- Subtask 6 – Representation of results*
- Subtask 7 – Documentation and manuscript writing: model development and LCA results*

Because of the repetition of these subtasks in each of the tasks, elements of the Statement of Work are repeated in individual task descriptions. An effort has been made to provide details relevant to each task in the associated subtask descriptions. Table 2 provides an overview of the anticipated activities associated with each task and subtask.

Table 2. Organization of Tasks

<i>Tasks</i>					
<i>Subtasks</i>	Base case municipal drinking water treatment (DWT) (4 variants)	Alternative disinfection technologies (LED UV, plasma bead UV, & ferrate)	Options for further treatment at point-of-use (GAC, conv. UV w/ GAC, ultrafiltration, LED UV w/ GAC, & plasma bead UV w/ GAC)	Base case wastewater treatment (WWT) (Cincinnati base case & conv. UV)	Peracetic acid (PAA) wastewater treatment
Develop a set of system descriptions	System descriptions for base case water treatment, using Figure 1 as a starting point and using the Greater Cincinnati Water Works (GCWW) as a reference. Including variations on base case representative of a range of systems currently in use.	Development of system descriptions for alternative drinking water disinfection technologies. Modification of other system descriptions for new technologies where necessary.	Addition of system descriptions for point-of-use systems. Further disinfection happens independently from and in series with base case DWT.	General representation following Figure 2 and using the Metropolitan Sewer District of Greater Cincinnati as a reference. Including consideration of the effects of overflow events and exposure risks.	General system same as base case with changes to disinfection component and amounts of selected other inputs
Data collection, unit process development, and impact assessment method augmentation: collect and process data from datasets, literature review, secondary sources, and through identifying and engaging relevant partners to produce life cycle inventory unit process datasets for use in modeling and to augment existing life cycle impact assessment methods	Start with available LCI unit process data. Interact with GCWW to obtain values for key parameters. Interact with EPA partners to obtain values for microfiltration. Add human health impacts associated with ingestion of disinfection by-products and exposure to microorganisms in drinking water based on information provided by EPA.	Interact with project partners to obtain data and develop unit processes for LED UV (Aquionics, LLC), Plasma bead UV (Imaging Systems Technology, Inc.), and ferrate (Battelle Labs and UMass Amherst). Check impacts and unit processes looking for missing or misrepresented flows that should be added or modified.	Adapt unit processes to developed under Tasks 1 & 2 to represent point-of-use treatment. Check impacts and unit processes looking for missing or misrepresented flows that should be added or modified.	Start with available LCI unit process data. Interact with MSDGC to obtain values for key parameters. Include process(es) representing overflow events. Addition of human health and ecosystem impacts associated with overflow events, characterized in a manner consistent with the USEtox model.	Interact with EPA NRMRL internal partners to obtain data and develop unit processes for peracetic acid based waste water treatment system. Check impacts and unit processes looking for missing or misrepresented flows that should be added or modified.
Collect and process economic data	Compile base case DWT infrastructure, operation, and maintenance costs from GCWW, other partners, and literature. Develop cost tables for base case systems.	Collect and/or estimate costs for production, operation, and maintenance of alternative disinfection systems through interaction with project partners, secondary data collection, and development of estimates in consultation with EPA Technical Team.	Collect and/or estimate costs for production, operation, and maintenance of point-of-use disinfection systems through interaction with project partners, secondary data collection, and development of estimates in consultation with EPA Technical Team.	Compile base case WWT infrastructure, operation, and maintenance costs from GCWW, other partners, and literature. Develop cost tables for base case systems.	Collect and/or estimate costs for production, operation, and maintenance of the PAA disinfection system through interaction with project partners, secondary data collection, and development of estimates in consultation with EPA Technical Team.
Incorporate unit processes and perform a reference set of model runs for base case	Incorporate unit process data into LCA software and ensure proper handling. Incorporate modified LCIA methods. Perform base case model validation. Generate contribution analysis results for base case.	Incorporate additional unit process data into LCA software and ensure proper handling. Connect new unit processes with those previously developed for the base case. Perform model validation. Generate contribution analysis results for alternative technologies.	Incorporate additional unit process data into LCA software and ensure proper handling. Connect new unit processes with those previously developed for the base case. Perform model validation. Generate contribution analysis results for alternative technologies.	Incorporate unit process data into LCA software and ensure proper handling. Incorporate modified LCIA methods. Perform base case model validation. Generate contribution analysis results for base case.	Incorporate additional unit process data into LCA software and ensure proper handling. Connect new unit processes with those previously developed for the base case. Perform model validation. Generate contribution analysis results for peracetic acid technology.
Sensitivity analysis and optional additional uncertainty analysis	Generate model results using low and high values for key model parameters.	Generate model results using low and high values for key model parameters.	Generate model results using low and high values for key model parameters.	Generate model results using low and high values for key model parameters.	Generate model results using low and high values for key model parameters.
Representation of results	Presentation of final system diagrams for the base case drinking water treatment systems and develop an appropriate presentation of contribution analysis, overall comparison across base case options for different impacts, costs, and sensitivity analysis.	Presentation of final system diagrams for the base case drinking water treatment systems and develop an appropriate presentation of contribution analysis, overall comparison across base case and alternatives for different impacts, cost-effectiveness, and sensitivity analysis.	Presentation of final diagrams for point-of-use systems, contribution analysis, overall comparison across base case and alternative DWT options, cost-effectiveness results, and representation of sensitivity analysis for the alternative technologies.	Presentation of diagram for wastewater treatment, contribution analysis by process, contribution analysis by environmental flow, cost breakdown by process, and representation of sensitivity analysis.	Presentation of diagram for wastewater treatment with PAA, comparative results for base case WWT and WWT with PAA: contribution analysis by process, contribution analysis by environmental flow, cost breakdown by process, and representation of sensitivity analysis.
Documentation and manuscript writing: model development and LCA results	Including: literature review of LCA of DWT, description of data sources and transformations for development of life cycle inventory processes, description of handling of human health impacts associated with drinking water ingestion, presentation of results, discussion of key sensitivities, and discussion of implications.	Including: literature review of LCA of UV, ferrate, and their application to drinking water treatment, description of data sources and transformations for development of life cycle inventory processes, references to the base case DWT manuscript, presentation of results, discussion of key sensitivities, and discussion of implications.	Including: background and literature review on the use of point-of-use treatment systems at hospitals and care facilities, description of the data sources and transformations for development of life cycle inventory processes, references to the previous two DWT manuscripts, presentation of key results, discussion of key sensitivities, and discussion of implications.	Including: literature review of LCA of WWT, description of data sources and transformations for development of LCI processes, description of handling of human health and ecosystem impacts associated with overflow events, presentation of results, discussion of key sensitivities, and discussion of implications.	Including: background on the use of peracetic acid for WWT, literature review of LCA studies of the use of peracetic acid for WWT, description of data sources and transformations for development of LCI unit processes, references to the base case WWT manuscript, presentation of results, discussion of sensitivities, and discussion of implications.

2.4. Task 1 – Life cycle assessment and economic assessment of base-case drinking water treatment

The objective of this task is to establish a flexible LCA model and associated economic accounts describing a base-case for drinking water acquisition, treatment, distribution, and use. The steps to accomplishing this are detailed in a series of subtask descriptions.

The key questions to be addressed under this task are:

- (1) What are the net life cycle impacts associated with the provision and use of drinking water?
- (2) What are the contributions of each life cycle stage to the net result for each impact category? What are the contributions of each step in the treatment process?
- (3) How do the three different base-case DWT options considered here compare to one another for each impact category?
- (4) What are the contributions of specific environmental releases to the net result for each technology and impact category?
- (5) What is the effect of plausible parameter variability? What parameters associated with source water quality have the greatest effect on net greenhouse gas and human health impact results? What parameters associated with uncertainty in concentration-time requirements for chemical-based disinfection or residence time requirements for UV-based disinfection have the greatest effect on net greenhouse gas and human health impact results? How does varying estimates of exposure to pathogens in drinking water effect their contribution to total human health results?

2.4.1. Subtask 1.1 - Develop a set of system descriptions for a reference model

The objective of this subtask is to develop a set of generalized system descriptions representative of a municipal DWT system. For the purposes of this project, the Greater Cincinnati Water Works will be adopted as a point of reference. The system descriptions developed within this subtask serve as a framework for the model to be developed in the subtasks, which follow. The reference systems are meant to be general enough they could be used to describe variation of the systems relevant for specific instances defined by characteristics such as differences in source characteristics and operational specifications and modular such the system descriptions could be used in different combinations to represent different DWT pathways.

Figure 1 contains the preliminary overarching system description that will be used for this work. In this subtask, the Contractor shall provide additional details underlying the processes defined in Figure 1 and define the reference flows between processes. This system is comprised of a series of DWT and other life cycle stages including the list that follows. Each of the processes shall be accompanied by the associated infrastructure components.

- (1) **Source water acquisition** – including pumping and piping from source water body and holding basins, screening large objects, transportation of water by pipeline to treatment facility, and storage of pre-treatment water on-site. The drinking water acquisition system should be described in a way, which includes acquisition of drinking water from surface water or an underground aquifer.

- (2) **Pre-chlorination** – chlorination of water prior to flocculation to prevent fouling of tanks and pipes.
- (3) **Flocculation** - consisting addition of coagulant and coagulant aid and mixing, considering alum as the coagulant
- (4) **Alum flocculant and aid production** – a reference supply chain representative of the average alum and flocculant aid used in the U.S.
- (5) **Sedimentation** – including the design of and activity occurring in the sedimentation basin and consideration of holding times/volumes.
- (6) **Disposal of sedimentation waste** - processes representing waste management practices. While the waste management practices considered for this project will most likely be based on the GCWW, the system description and model should be general enough to accommodate the prevailing methods flocculated waste treatment used across the U.S.
- (7) **Filtration** – considering a sand and anthracite filter and including replacement of filter materials during normal operation life of the filters.
- (8) **Backflushing** – cleaning and regeneration of the sand and anthracite filter through reverse filtering clean water, the associated “loss-rate” of treated water, and the recirculation of settled backwash water to the head-of-works.
- (9) **Adsorption** – operation of a granular activated carbon (GAC) system for further disinfection.
- (10) **Granular activated carbon production** – a reference supply chain representative of average granular activated carbon used in U.S. DWT systems.
- (11) **Granular activated carbon regeneration** – following a conventional thermal regeneration method including consideration of typical energy sources used for this purpose as well as carbon loss and replacement (based on GCWW data).
- (12) **Microfiltration** – representative of the system, which would be used in a municipality with a water source considered, suited to microfiltration.
- (13) **Conditioning** – pH adjustment using lime
- (14) **Lime production** – a reference supply chain representative of average lime used in U.S. DWT systems.
- (15) **Disinfection** – representative of a conventional DWT system using gaseous chlorine for primary disinfection and sodium hypochlorite to provide the required level of disinfectant throughout the distribution system.
- (16) **Gaseous chlorine production** – a reference supply chain representative of average gaseous chlorine used in U.S. DWT systems.
- (17) **Sodium hypochlorite production** – a reference supply chain representative of average sodium hypochlorite used in U.S. DWT systems.
- (18) **Conventional ultraviolet disinfection operation** – energy and other inputs representative of operation of a typical conventional medium-pressure UV system used in U.S. DWT systems.
- (19) **Conventional ultraviolet disinfection system production** – a reference supply chain representative of an average UV system used in U.S. DWT systems.
- (20) **Fluorination** – addition of 1 ppm fluoride prior to distribution.
- (21) **Fluoride production** - a reference supply chain representative of average sodium fluorosilicate used in U.S. DWT systems.

- (22) **Distribution** - of drinking water to end users including pipe infrastructure, pressurizing components, reservoirs, and disinfectant booster stations, as well as consideration of leakage, groundwater infiltration, corrosion, and failure events.
- (23) **Drinking water use** – considering ingestion of water as the specific use and including consideration of exposure and biological response to pathogens of interest and disinfection by-products.

For each description the Contractor shall: (a) produce a set of system diagrams and simplified versions of the system diagrams for inclusion in presentations using MS Visio or similar software to be agreed upon with the Work Assignment Manager and (b) write descriptions of: (i) the systems to be analyzed including descriptions of relevant technosphere and natural processes, (ii) the impacts to be tracked and their relevance to the system, (iii) a list of key parameters and initial hypotheses regarding their relative importance for results in key impact categories (i.e., global warming potential), and (iv) the data sources to be used and the transformations necessary to incorporate them into the model. These descriptions serve as a basis for prioritizing and allocating time to data collection and model development activities.

- Milestones:
- (M-1.1.1) **Draft system description** – draft version of the system descriptions in the form of a Microsoft Word file including figures pasted from Visio and associated descriptions for review
 - (M-1.1.2) **Revised system description** – modified version of the system description (M-1.1.1) with all review comments addressed
 - (M-1.1.3) **Revised Visio diagrams** – a zip file containing the diagrams in their original editable format

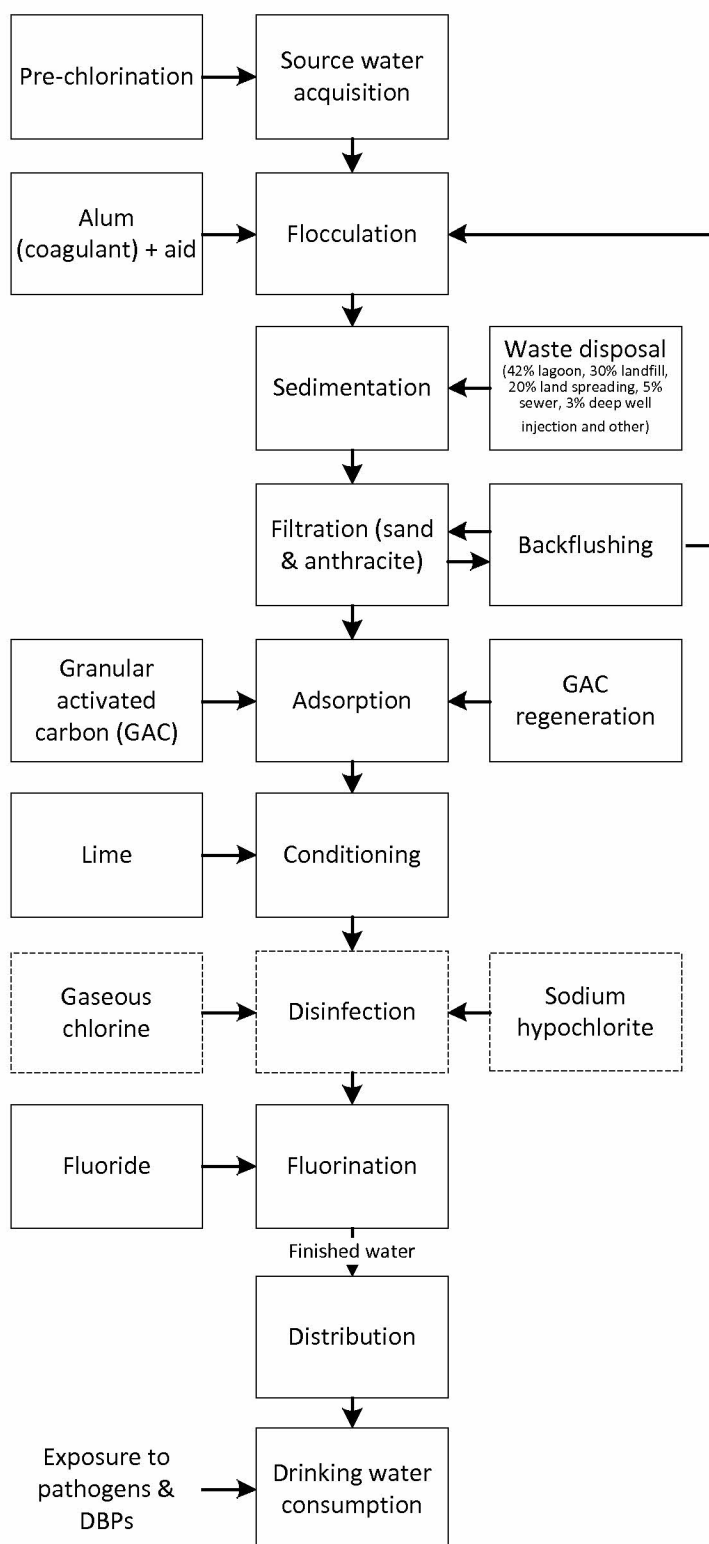


Figure 1. System description for base case drinking water treatment system representative of Cincinnati. Dotted boxes represent processes, which are modified to represent disinfection alternatives.

2.4.2. Subtask 1.2 – Data collection and unit process development: collect and process data from datasets, literature review, secondary sources, and through identifying and engaging partners to produce life cycle inventory unit process datasets for use in modeling

The Contractor shall: (a) collect the necessary data from relevant datasets, literature review, secondary sources, and through coordinating with partners via phone calls and email exchanges; (b) organize a data archive including clearly documented original data and transformations; and (c) process data from its received format into unit process data consistent with use in an LCA model and including relevant metadata.

When data are available within existing models, these should be assessed and any necessary modifications identified. These models may include standard LCA datasets such as EcoInvent, GaBi, and the US LCI, but should include consideration of non-LCA-specific models and datasets as well. During the course of data collection, an effort shall be made to identify potential partners who have and are willing to share otherwise unpublished data relevant for this work. EPA has engaged the Greater Cincinnati Water Works (GCWW) in this work. The Contractor shall correspond with GCWW contacts provided by EPA to obtain relevant data based on their process. No travel is anticipated in connection with partner engagement for data collection purposes.

Figure 1 and the list provided in the preceding subtask together with the associated system descriptions will serve as the basis for unit process development. Unit processes will be developed with the understanding that establishing a comprehensive model form capable including parameters governing individual unit processes is the primary objective. Efforts to assign values to parameters and flows will be conducted on an iterative basis with the goal being to establish a base set of values and work from there to improve upon the base set according to the results of (a) model beta run(s). During the course of this subtask, the Contractor shall review the system descriptions with the Work Assignment Manager and according to the findings establish an approach to unit process and model development.

The Contractor shall use parameters to govern the inputs and outputs of unit processes to account for a range of values for organic matter concentration, sediment concentration, iron sulfide concentration, water temperature, concentration-time (Ct) for chemical disinfectants and UV-fluence for UV disinfection required for 3-4 log reductions of pathogens including *Cryptosporidium*, *Giardia*, *Legionella*, adenoviruses and enteroviruses., disinfection by-products including trihalomethane and haloacetic acids, and concentrations of pathogens throughout the water life cycle including *Cryptosporidium*, *Giardia*, *Legionella*, adenoviruses and enteroviruses.

The Contractor shall: (a) produce the necessary additional life cycle inventory unit processes using a template including files in Microsoft Word and Excel format and (b) import unit process data into the openLCA software package.

All LCA unit process data developed within the context of this agreement will be provided by the Contractor to EPA in the form of Microsoft Word and Excel documentation using templates provided by EPA. An example of the Microsoft Word template is provided in an Appendix. The goal of the data template is to capture the original data and transformations used to develop unit

processes in a format, which can be traced back by a knowledgeable practitioner and efficiently updated by others in follow on work. However, it is the intention that data collection and documentation should be performed efficiently considering the limited time and resources.

While the goal of this work is to establish a fully transparent set of LCA unit processes, it is clear that background LCA databases such as EcoInvent, US LCI, and/or GaBi should be used to allow for efficient estimation of upstream impacts. To the extent that existing LCA background data are used to provide results for upstream impacts, these data shall come from a dataset that has been quality checked and which is publicly available at a reasonable cost (i.e. EcoInvent). The Contractor shall alert EPA to unit process data already existing within unit processes developed prior to this agreement before incorporating them in the LCA models developed under this agreement.

- Milestones: (M-1.2.1) **Draft Unit Processes** – a zip file or similar containing unit processes used in this Statement of Work provided for review. Unit processes shall be provided in the form of MS Word and Excel files as described above.
- (M-1.2.2) **Electronic data collection archive** – a zip file or similar containing the results of data collection in the form of PDF and other files organized in labeled folders
- Deliverables: (D-1.2.1) **Unit Processes (revised)** – a zip file or similar containing modified versions of the draft unit processes (M-2.1) following incorporation of review comments

2.4.3. Subtask 1.3 – Collect and process economic data for base case drinking water treatment

The objective of this subtask is to develop an account of the economic structure of DWT. The product of this work will be a series of spreadsheets describing the infrastructure costs for the base case DWT facility and the operation and maintenance costs associated with each of the DWT and distribution processes. To the extent possible, these accounts will include information provided by the Greater Cincinnati Water Works. Where data are not available from GCWW, gaps will be filled with values from the literature and best estimates using proxy values and/or expert judgment when better values are not available. These economic accounts shall parallel the life cycle inventory through matching life cycle inventory input and output names with those associated with the cost data. In cases where additional economic details are available, inputs and outputs shall be decomposed into subcomponents. , additional information will be required to balance the economic accounts such as salaries, purchased services not represented in the life cycle inventory, and interest paid on borrowed funds. The account for infrastructure shall include key facility components, which, together with other construction and management costs, are representative of the initial cost of the DWT facility. The account for operation and maintenance shall be broken out into each of the DWT and distribution processes described in the preceding subtasks. When necessary, infrastructure accounts will be provided for key maintenance inputs.

An initial step in this work shall be to develop a framework for collecting cost information based on the life cycle inventory processes. This format will be shared with the Greater Cincinnati Water Works and other project partners as deemed appropriate to collect the required data.

When supplemental data are collected from the literature, the associated files shall be organized and saved in an electronic archive to be provided to EPA for future reference. No confidential business information is anticipated to be collected in this subtask and thus no non-disclosure agreements will be executed. All data collected shall be provided to EPA and disseminated publicly by EPA at its discretion.

- Milestones: (M-1.3.1) **Draft economic account** – a series of spreadsheets containing accounts for infrastructure components, construction processes, operation and maintenance processes, and key infrastructure requirements associated with maintenance. Unit processes shall be provided in the form of Excel files with accompanying documentation.
- (M-1.3.2) **Electronic data collection archive** – a zip file or similar containing the results of data collection in the form of PDF and other files organized in labeled folders
- Deliverables: (D-1.3.1) **Economic account (revised)** – a zip file or similar containing modified versions of the economic account (M-1.3.1) following incorporation of review comments

2.4.4. Subtask 1.4 – Incorporate unit processes and perform a reference set of model runs for base case drinking water treatment

The objectives of this subtask are (1) to ensure the unit processes are properly incorporated into the LCA model and then (2) to use the model to generate results for the base case set of model runs to address the questions posed in the first section of the task description and additional questions identified in the course of the work as agreed upon with the EPA Work Assignment Manager. The LCA model shall be: (a) developed within an appropriate LCA software platform which allows for full conversion to the open LCA software platform by EPA, (b) based on transparent, public or commercially-available background data, and (c) submitted to EPA for quality assurance and review of unit process data at appropriate points in the project timeline to allow for the Contractor to incorporate EPA-provided comments/revisions.

The system descriptions and questions open the possibility for a large number of combinations of options for model runs. Because of the limited resources available to carry out this Statement of Work, it is understood that it is not possible to run all combinations. For this reason, a list of anticipated base set of model runs for base case DWT are detailed in the columns on the left in Table 3. Sensitivity analysis runs are described in a subsequent subtask. While the runs identified in Table 3 are not definitive or exclusive, they are intended to provide guidance regarding the level of effort anticipated associated with generating model results. If during the course of carrying out the preceding subtasks it is determined that modifications to this list are warranted, these modifications shall be made in such a way the overall level of effort required to carry out this and other subtasks is not effected. Note that additional model runs for sensitivity analysis are described below.

Table 3. Base case model runs to be evaluated under this Statement of Work, reference set and sensitivity analysis.

		Base case drinking water treatment				Sensitivity analysis for base case																	
		Base case incl. sorption	Base case w/o sorption	Base case w/ conventional UV	No flocculation	Source water quality								CT/RT				DBP				Pathogen	
						Base case, low [OM]	Base case, high [OM]	Base case, low [SED]	Base case, high [SED]	Base case, low [Fe]	Base case, high [Fe]	Base case, low temp.	Base case, high temp.	Base case, low CT	Base case, high CT	Base case UV, low RT	Base case UV, high RT	Base case, low TTHM	Base case, high TTHM	Base case, low HAA5	Base case, high HAA5	Base case, low pathogen	Base case, high pathogen
Drinking water acquisition	Surface water	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Undergr. aquifer																						
Pre-disinfection	Pre-filtration	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Flocculation/sedimentation	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Filtration (sand & anthracite)	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	GAC sorption	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Microfiltration				X																		
	Conditioning	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Primary disinfection	Gaseous chlorine	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Conventional UV			X	X											X	X						
	LED UV																						
	Plasma bead UV																						
	Ferrate																						
Secondary disinfection	Hypochlorite	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Distribution	Base case infrastructure	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Fluoride	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Point-of-use treatment	Conventional UV																						
	LED UV																						
	Plasma bead UV																						
	Granular activated carbon																						
Drinking water use	Healthy adult	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Child																						
	Immunocompromised adult																						
Impacts tracked	Full suite of impacts	X	X	X	X																		
	Human health					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Primary energy demand					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Global warming potential																						
	Ecotoxicity																						
Monetary values tracked	Infrastructure	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Operation & maintenance	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Externality valuation	X	X	X	X																		
Multi-attribute metrics tracked	Energy	X	X	X	X																		
	Ecological footprint	X	X	X	X																		
Source water quality	Organic matter, high					X																	
	Organic matter, base	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Organic matter, low					X																	
	Sediment, high							X															
	Sediment, base	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sediment, low						X																
	Iron, high									X													
	Iron, base	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Iron, low								X														
	Temperature, high											X											
	Temperature, base	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X
	Temperature, low											X											
Concentration-time (CT) & UV residence time (RT) requirement	High					X		X		X				X		X							
	Base	X	X	X	X				X	X							X	X	X	X	X	X	X
	Low					X	X					X	X		X								
Exposure to disinfection by-products	TTHM, high																	X					
	TTHM, base	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
	TTHM, low																X						
	HAA5, high																			X			
	HAA5, base	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X
	HAA5, low																	X					
Exposure to pathogens	High																					X	
	Base	X	X	X	X	Governed by model parameters								X	X	X	X	X	X	X			
	Low																				X		
Run ID	Unique system number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22

Following a review of preliminary results by the EPA Work Assignment Manager, the results shall be documented in tabular form in an Excel or similar spreadsheet file. This documentation shall include sufficient commenting to identify the systems and parameters represented by each run and shall include a breakdown of results by impact and DWT process/life cycle stage.

- Milestones: (M-1.4.2) **Results for reference set of model runs for base case drinking water treatment** – tabular results for the model runs and sensitivity analysis provided electronically in an Excel or similar file
- Deliverables: (D-1.4.1) **Life cycle inventory database** - a file exported from the LCA software such as a GaBi exchange file (or standard LCA data exchange format such as ILCD or Ecospol) and provided electronically

2.4.5. Subtask 1.5 - Sensitivity analysis and optional additional uncertainty analysis

The objective of this subtask is to explore the effects of modeling choices and variability. The Contractor shall conduct a sensitivity analysis to understand the effect of variability in key parameters on the results of the LCA model. Key parameters shall be identified in consultation with the EPA Work Assignment Manager. The effect of variability shall be assessed parametrically and the results presented in the form of appropriate tables or figures. To provide a clear basis for estimating the level of effort required, a set of model runs anticipated to be evaluated is provided in the columns on the right of Table 3.

Sensitivity analysis as envisioned prior to beginning this work, involves assessing variation of parameters related to source water characteristics, concentration-time and UV residence time requirements, exposure to disinfection by-products, and exposure to pathogens. Tracked source water characteristics include concentrations of organic matter, sediment, and iron as well as water temperature. Tracked disinfection by-products include trihalomethane and haloacetic acids. Tracked pathogens include *Cryptosporidium* & *Giardia* oo/cysts, *Legionella*, adenoviruses and enteroviruses. For the purposes of this sensitivity analysis, model runs will be performed for representative low and high cases for model parameters as detailed in Table 3.

If during the course of carrying out the preceding subtasks it is determined that modifications to the model runs represented in Table 3 are warranted, these modifications shall be made in such a way the overall level of effort required to carry out this and other subtasks is not effected.

- Milestones: (M-1.5.1) **Results for base case drinking water treatment sensitivity analysis** – tabular results for the sensitivity analysis model runs provided electronically in an Excel or similar file

2.4.6. Subtask 1.6 - Representation of results

The objective of this subtask is to develop a set of intuitive, well-edited figures presenting a set of key results from the model runs and economic accounts appropriate for engaging decision-makers. To accomplish this subtask, the Contractor shall engage in discussion with the EPA Work Assignment Manager, select key results and key sources of variability to be presented based on the discussion, develop a draft set of figures for EPA review, and revise figures according to review comments received from the Work Assignment Manager. This work will

involve performing additional spreadsheet calculations and data manipulations to combine economic and life cycle impact results and to draw out important features of the data. The final set of results shall reflect key aspects of the analysis, which will be expanded on in the discussion provided in the manuscript produced in the subsequent subtask.

Milestones: (M-1.6.1) **Draft key figures for the base case** – key figures provided electronically in an Excel or similar file for review

Deliverables: (D-1.6.2) **Key figures for the base case (revised)** – revised version of the draft key figures (M-1.6.1) modified in response to comments

2.4.7. Subtask 1.7- Documentation and manuscript writing: model development and LCA results for the base case drinking water treatment systems

The objective of this subtask is to document the model and results produced in the preceding subtasks in a manuscript and associated supporting information in a format appropriate for submission to a scientific journal. To accomplish this, the Contractor shall: (a) write sections of a manuscript presenting model development and LCA and economic results for the base case DWT systems, (b) respond to comments provided through an internal peer-review process coordinated by the EPA Work Assignment Manager, (c) prepare and format materials in accordance with the specifications for the journal agreed upon through discussion with the EPA Work Assignment Manager, and (d) assist EPA in responding to comments received from the journal peer-reviewers in coordination with the EPA Work Assignment Manager. It is anticipated the EPA Work Assignment Manager and/or (a) member(s) of the EPA Technical Team will provide significant input to the manuscript and serve as (a) co-author(s).

This manuscript shall contain at minimum the following sections: abstract, literature review, method, results, sensitivity analysis, and discussion and shall be accompanied by a document containing supporting information (SI). The abstract shall highlight key points from the article focusing on key quantitative insights. The literature review shall provide context for the work performed within the preceding subtasks including presenting key findings from previous studies, placing this study within the context of prior studies, and describing previous studies and data collection efforts, which were utilized in the development of the LCA model developed within this Statement of Work. The method shall include system diagrams, descriptions of the unit processes that make up the systems, a brief description of the impact assessment methods used in the model, a description of the impact assessment methods used to quantify risk associated with pathogens and toxins in drinking water, a brief description of the economic accounts and data sources, and references to more detailed information provided in the SI. The results shall include selected key figures, references to more detailed results provided in the SI. Similarly, the sensitivity analysis shall provide a description of the results of the sensitivity analysis, selected figures and/or tables, and references to more detailed sensitivity results provided in the SI. The discussion shall address the interpretation of results, strengths, and limitations of the results and approach, implications of results for decision-making, and next steps for further investigation of questions that arise in the course of this work. The SI shall include more detailed quantitative information necessary for understanding the model, other diagrams and results produced in not included in the main manuscript, and text documenting the supporting information.

- Milestones: (M-1.7.1) **Draft Task 1 manuscript** – draft version of the manuscript for project internal peer-review as described above
- (M-1.7.2) **Response to peer-review of Task 1 manuscript** – including a revised version of the submitted manuscript (D-1.7.1) modified to address comments received through external peer-review and a Word file containing itemized responses to reviewer comments
- Deliverables: (D-1.7.1) **Task 1 manuscript: Model Development and LCA Results for Drinking Water Treatment Options (revised and formatted)** – revised version of the draft manuscript (M-1.7.1) formatted for submission to an appropriate peer-reviewed, scientific journal

Task 2 – LCA and economic comparison of alternative disinfection technologies

The objective of this task is to establish a flexible LCA model and associated economic accounts describing alternative disinfection methods within the context of the full drinking water lifecycle. This Task builds upon the base case models developed in Task 1 and its subtask structure parallels that of Task 1.

The key questions to be addressed in this task are:

- (1) What is the net life cycle impacts associated with the provision and use of drinking water for each of the alternatives?
- (2) For which life cycle stages do the results for drinking water alternatives differ from the base case? What are the differences?
- (3) What is the relationship between differences in impact results for life cycle stages and specified flows of interest?
- (4) What is the effect of plausible parameter variability? What parameters associated with source water quality have the greatest effect on net greenhouse gas and human health impact results? What parameters associated with uncertainty in concentration-time requirements for chemical-based disinfection or residence time requirements for UV-based disinfection have the greatest effect on net greenhouse gas and human health impact results? How does varying estimates of exposure to pathogens in drinking water effect their contribution to total human health results?

2.4.8. Subtask 2.1 - Develop a set of system descriptions for disinfection alternatives

The objective of this subtask is to develop a set of generalized system descriptions representative of operating a municipal DWT system with 3 alternative disinfection technologies, LED UV, plasma bead UV, and ferrate. These system descriptions shall be created in a way in which they could replace the *disinfection* and *drinking water use* stages within the model developed under Task 1 to represent alternative full life cycles for drinking water treated using these 3 technologies. Together with the system descriptions developed under Task 1, the system descriptions developed within this subtask serve as a framework for the model to be developed in the subtasks, which follow. While *disinfection* and *drinking water use* are anticipated to be the primary components of the overall drinking water life cycle effected by the alternative technologies, the need to adjust other system descriptions first developed in Task 1 will be considered under this subtask.

The alternative disinfection technologies will be primarily represented by the subsystems included in the list that follows. In this subtask, the Contractor shall provide additional details underlying the systems listed below and define the reference flows between processes. Each of the processes shall be accompanied by the associated inputs and infrastructure components.

- (1) **Disinfection with LED UV, operation** – operation of a DWT system using ferrate for primary disinfection and sodium hypochlorite to provide the required level of disinfectant throughout the distribution system.
- (2) **LED UV system production** – a reference supply chain representative of a large-scale LED UV system.
- (3) **Disinfection with plasma bead UV, operation** – operation of a DWT system using plasma bead UV for primary disinfection and sodium hypochlorite to provide the required level of disinfectant throughout the distribution system.
- (4) **Plasma bead UV system production** – a reference supply chain representative of the production of a hypothetical large-scale plasma bead UV system.
- (5) **Disinfection with ferrate, operation** – operation of a DWT system using ferrate for primary disinfection and sodium hypochlorite to provide the required level of disinfectant throughout the distribution system.
- (6) **Ferrate production** – a reference supply chain representative of average ferrate used in the U.S.
- (7) **Drinking water use** – descriptions of the changes in exposure to disinfection by-products and pathogens associated with the implementation of each alternative disinfection approach.

For each description the Contractor shall: (a) produce a set of system diagrams and simplified versions of the system diagrams for inclusion in presentations using MS Visio or similar software to be agreed upon with the Work Assignment Manager and (b) write descriptions of: (i) the systems to be analyzed including descriptions of relevant technosphere and natural processes, (ii) the impacts to be tracked and their relevance to the system, (iii) a list of key parameters and initial hypotheses regarding their relative importance for results in key impact categories (i.e., global warming potential), and (iv) the data sources to be used and the transformations necessary to incorporate them into the model. These descriptions serve as a basis for prioritizing and allocating time to data collection and model development activities.

- Milestones:
- (M-2.1.1) **Draft system description** – draft version of the system descriptions in the form of a Microsoft Word file including figures pasted from Visio and associated descriptions for review
 - (M-2.1.2) **Revised system description** – modified version of the system description (M-2.1.1) with all review comments addressed
 - (M-2.1.3) **Revised Visio diagrams** – a zip file containing containing the diagrams in their original editable format

2.4.9. Subtask 2.2 – Data collection and unit process development

The objective of this subtask is to compile the information needed to develop the LCA model in the subsequent subtasks. To accomplish this, the Contractor shall: (a) collect the necessary data from relevant datasets, literature review, secondary sources, and through coordinating with

partners via phone calls and email exchanges; (b) organize a data archive including clearly documented original data and transformations; and (c) process data from its received format into unit process data consistent with use in an LCA model and including relevant metadata. The guidelines for carrying out this subtask are the same as those governing subtask 1.2.

Data for these technologies shall be obtained through literature review and through interacting with EPA partner organizations involved in their development. The first technology, relying on UV category C short wave radiation (UV-C) has recently been commercialized by Aquionics, Inc. located in Erlanger, Kentucky. The second technology, plasma bead UV, is under development by Imaging Systems Technologies located in Toledo, Ohio. The EPA Work Assignment Manager will facilitate the engagement of these companies in providing necessary data. UV disinfection has been investigated by the US EPA Environmental Technology Verification Program for drinking water treatment (<http://www.epa.gov/nrmrl/std/etv/vt-dws.html#uoaiddot>) and through an initial LCA analysis. The third technology, disinfection with ferrate, is under development by Ferrate Treatment Technologies. A contact at Ferrate Treatment Technologies and a second research group at Battelle have agreed to work with EPA to evaluate the prospects for widespread use of ferrate as a disinfectant. Ferrate is being tested locally within the National Risk Management Research Laboratory at the lab scale. Results from these studies can be incorporated into this work.

The previously developed system descriptions will serve as the basis for unit process development with the goal of establishing a comprehensive model form capable including parameters governing individual unit processes. Efforts to assign values to parameters and flows will be conducted on an iterative basis with the goal being to establish a base set of values and work from there to improve upon the base set according to the results of model beta runs. The Contractor shall use parameters to govern the inputs and outputs of unit processes to account for a range of values for organic matter concentration, sediment concentration, iron sulfide concentration, water temperature, concentration-time (Ct) for chemical disinfectants, UV fluence (in $\text{mJ}\cdot\text{cm}^2$) for UV disinfection, disinfection by-products including trihalomethane and haloacetic acids, and pathogens including *Cryptosporidium* & *Giardia* oocysts, *Legionella*, adenoviruses and enteroviruses. During the course of this subtask, the Contractor shall review the system descriptions with the Work Assignment Manager and according to the findings establish an approach to unit process and model development.

To complete this subtask, Contractor shall: (a) produce the necessary additional life cycle inventory unit processes using a template including files in Microsoft Word and Excel format and (b) import unit process data into the openLCA software package.

The requirements and guidance provided in subtask 1.2 regarding provision of data to EPA, documentation format, allocation of time, the use of background datasets apply to this subtask.

- Milestones:
- (M-2.2.1) **Draft Unit Processes** – a zip file or similar containing unit processes used in this Statement of Work provided for review. Unit processes shall be provided in the form of MS Word and Excel files as described above.
 - (M-2.2.2) **Electronic data collection archive** – a zip file or similar containing

the results of data collection in the form of PDF and other files organized in labeled folders

Deliverables: (D-2.2.1) **Unit Processes (revised)** – a zip file or similar containing modified versions of the draft unit processes (M-2.2.1) following incorporation of review comments

2.4.10. Subtask 2.3 – Collect and process economic data for municipal-scale disinfection alternatives

The objective of this subtask is to develop an account of the economic structure of DWT using the three alternative treatment technologies. The product of this work will be a series of spreadsheets describing the infrastructure, operation, and maintenance costs for drinking water systems utilizing the alternative DWT technologies. This account shall be consistent with and directly build upon the economic accounts developed under Task 1. The Contractor shall collect the additional cost information associated with processes representative of the alternative technologies and integrate them with the appropriate portions of the base case spreadsheet accounts. Cost data will be collected from project partners using a format similar to the one developed under Task 1. This shall be supplemented with data from the literature where necessary. The electronic files associated with data collection and literature search shall be organized and saved in an electronic archive to be provided to EPA for future reference. All data collected shall be provided to EPA and disseminated publicly by EPA at its discretion.

Milestones: (M-2.3.1) **Draft economic account** – a series of spreadsheets containing accounts for infrastructure components, construction processes, operation and maintenance processes, and key infrastructure requirements associated with maintenance. Unit processes shall be provided in the form of Excel files with accompanying documentation.

(M-2.3.2) **Electronic data collection archive** – a zip file or similar containing the results of data collection in the form of PDF and other files organized in labeled folders

Deliverables: (D-2.3.1) **Economic account (revised)** – a zip file or similar containing modified versions of the economic account (M-2.3.1) following incorporation of review comments

2.4.11. Subtask 2.4 – Incorporate unit processes and perform the reference set of LCA model runs for disinfection alternatives

The objectives of this subtask are (1) to ensure the unit processes are properly incorporated into the LCA model and then (2) to use the model to generate results for the a reference set of model runs for disinfection alternatives to address the questions posed in the first section of the Task 2 description and additional questions identified in the course of the work as agreed upon with the EPA Work Assignment Manager. The LCA model shall be: (a) developed within an appropriate LCA software platform which allows for full conversion to the open LCA software platform by EPA, (b) based on transparent, public or commercially-available background data, and (c) submitted to EPA for quality assurance and review of unit process data at appropriate points in the project timeline to allow for the Contractor to incorporate EPA-provided comments/revisions.

A list of anticipated reference set of model runs for disinfection alternatives are detailed in the columns on the left in Table 3a. Sensitivity analysis runs are presented on the right side of Table 3a and in Table 3b and described in a subsequent subtask. While the runs identified in Table 3a are not definitive or exclusive, they are intended to provide guidance regarding the level of effort anticipated associated with generating model results. If during the course of carrying out this Task it is determined that modifications to this list are warranted, these modifications shall be made in such a way the overall level of effort required to carry out the Task is not affected.

Following a review of preliminary results by the EPA Work Assignment Manager, the results shall be documented in tabular form in an Excel or similar spreadsheet file. This documentation shall include sufficient commenting to identify the systems and parameters represented by each run and shall include a breakdown of results by impact and DWT process/life cycle stage.

- Milestones: (M-2.4.2) **Results for reference set of model runs for disinfection alternatives** – tabular results for the model runs and sensitivity analysis provided electronically in an Excel or similar file
- Deliverables: (D-2.4.1) **Updated life cycle inventory database** - a file exported from the LCA software such as a GaBi exchange file (or standard LCA data exchange format such as ILCD or Ecospol) and provided electronically

2.4.12. Subtask 2.5 - Sensitivity analysis and optional additional uncertainty analysis

The Contractor shall conduct a sensitivity analysis to understand the effect of variability in key parameters on the results of the LCA model. Key parameters shall be identified in consultation with the EPA Work Assignment Manager. The effect of variability shall be assessed parametrically and the results presented in the form of appropriate tables or figures. To provide a clear basis for estimating the level of effort required, a set of model runs anticipated to be evaluated is provided in the columns on the right of Table 3a and in Table 3b.

Sensitivity analysis as envisioned prior to beginning this work, involves assessing variation of parameters related to source water characteristics, concentration-time and UV residence time requirements, exposure to disinfection by-products, and exposure to pathogens. Tracked source water characteristics include concentrations of total and dissolved organic matter (TOC, DOC), suspended solids, and iron as well as water temperature. Tracked disinfection by-products include trihalomethane and haloacetic acids. Tracked pathogens include *Cryptosporidium* & *Giardia* oocysts, *Legionella*, adenoviruses and enteroviruses. . For the purposes of this sensitivity analysis, model runs will be performed for representative low and high cases for model parameters as detailed in Table 3.

If during the course of carrying out this Task it is determined that modifications to the model runs represented in Table 3 are warranted, these modifications shall be made in such a way the overall level of effort required to carry out the Task is not effected.

- Milestones: (M-2.5.1) **Sensitivity analysis results for disinfection alternatives** – tabular results for the sensitivity analysis model runs provided electronically in an Excel or similar file

Table 3a. Reference and sensitivity model runs for disinfection alternatives.

		Disinfection alternatives						Sensitivity analysis for disinfection alternatives																	
		Base case			No flocculation			CT/RT						Pathogen											
		Base case w/ LED UV	Base case w/ plasma bead UV	Base case w/ ferrate	No flocculation w/ LED UV	No flocculation w/ plasma bead UV	No flocculation w/ ferrate	Base case w/ ferrate, low CT	Base case w/ ferrate, high CT	Base case w/ LED UV, low RT	Base case w/ LED UV, high RT	Base case w/ plasma bead UV, low RT	Base case w/ plasma bead UV, high RT	Base case w/ LED UV, low pathogen	Base case w/ LED UV, high pathogen	Base case w/ plasma bead UV, low pathogen	Base case w/ plasma bead UV, high pathogen	Base case w/ ferrate, low pathogen	Base case w/ ferrate, high pathogen						
Drinking water acquisition	Surface water	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Pre-disinfection	Undergr. acquifer																								
	Pre-filtration	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Flocculation/sedimentation	X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Filtration (sand & anthracite)	X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	GAC sorption	X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Microfiltration				X	X	X																		
Disinfection	Conditioning	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Gaseous chlorine	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Conventional UV																								
	LED UV	X			X						X	X			X	X									
	Plasma bead UV		X			X							X	X			X	X							
Distribution	Ferrate			X			X	X	X												X	X			
	Hypochlorite	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Point-of-use treatment	Base case infrastructure	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Conventional UV																								
Drinking water use	LED UV																								
	Plasma bead UV																								
	Granular activated carbon																								
Impacts tracked	Healthy adult	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Child																								
	Immunocompromised adult																								
Monetary values tracked	Full suite of impacts	X	X	X	X	X	X																		
	Human health								X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Primary energy demand								X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Global warming potential																								
Multi-attribute metrics tracked	Ecotoxicity																								
	Infrastructure	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Operation & maintenance	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Source water characteristics	Externality valuation	X	X	X	X	X	X																		
	Emergency	X	X	X	X	X	X																		
Exposure to disinfection by-products	Ecological footprint	X	X	X	X	X	X																		
	Organic matter, high																								
	Organic matter, base	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Organic matter, low																								
	Sediment, high																								
	Sediment, base	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Sediment, low																								
	Iron, high																								
	Iron, base	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Iron, low																								
	Temperature, high																								
	Exposure to pathogens	Temperature, base	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Temperature, low																									
High									X		X		X					X		X				X	
Run ID	Base	X	X	X	X	X	X							X	X	X	X	X	X	X	X	X	X	X	
	Low							X		X		X													
	Unique system number	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40						

Table 3b. Reference and sensitivity model runs for disinfection alternatives (continued).

		Sensitivity analysis for disinfection alternatives																							
		Source water quality																							
		Base case w/ LED UV, low [OM]	Base case w/ LED UV, high [OM]	Base case w/ LED UV, low [SED]	Base case w/ LED UV, high [SED]	Base case w/ LED UV, low [Fe]	Base case w/ LED UV, high [Fe]	Base case w/ LED UV, low temp.	Base case w/ LED UV, high temp.	Base case w/ plasma bead UV, low [OM]	Base case w/ plasma bead UV, high [OM]	Base case w/ plasma bead UV, low [SED]	Base case w/ plasma bead UV, high [SED]	Base case w/ plasma bead UV, low [Fe]	Base case w/ plasma bead UV, high [Fe]	Base case w/ plasma bead UV, low temp.	Base case w/ plasma bead UV, high temp.	Base case w/ ferrate, low [OM]	Base case w/ ferrate, high [OM]	Base case w/ ferrate, low [SED]	Base case w/ ferrate, high [SED]	Base case w/ ferrate, low [Fe]	Base case w/ ferrate, high [Fe]	Base case w/ ferrate, low temp.	Base case w/ ferrate, high temp.
Drinking water acquisition	Surface water	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Undergr. aquifer																								
Pre-disinfection	Pre-filtration	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Flocculation/sedimentation	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Filtration (sand & anthracite)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	GAC sorption	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Microfiltration																								
	Conditioning	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Disinfection	Gaseous chlorine	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Conventional UV																								
	LED UV	X	X	X	X	X	X	X	X																
	Plasma bead UV									X	X	X	X	X	X	X	X								
	Ferrate																	X	X	X	X	X	X	X	X
	Hypochlorite	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Distribution	Base case infrastructure	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Point-of-use treatment	Conventional UV																								
	LED UV																								
	Plasma bead UV																								
	Granular activated carbon																								
Drinking water use	Healthy adult	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Child																								
	Immunocompromised adult																								
Impacts tracked	Full suite of impacts																								
	Human health	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Primary energy demand	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Global warming potential																								
	Ecotoxicity																								
Monetary values tracked	Infrastructure	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Operation & maintenance	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Externality valuation																								
Multi-attribute metrics tracked	Energy																								
	Ecological footprint																								
Source water characteristics	Organic matter, high		X								X								X						
	Organic matter, base			X	X	X	X	X	X			X	X	X	X	X	X			X	X	X	X	X	X
	Organic matter, low	X								X								X							
	Sediment, high				X							X									X				
	Sediment, base	X	X			X	X	X	X	X				X	X	X	X	X				X	X	X	X
	Sediment, low			X								X							X						
	Iron, high						X								X								X		
	Iron, base	X	X	X	X			X	X	X	X	X	X				X	X	X	X	X			X	X
	Iron, low					X									X										
	Temperature, high								X								X								X
	Temperature, base	X	X	X	X	X				X	X	X	X	X	X			X	X	X	X	X	X		
	Temperature, low							X									X							X	
Concentration-time (CT) & UV residence time (RT) requirement	High																								
	Base	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Low																								
Exposure to disinfection by-products	TTHM, high																								
	TTHM, base	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	TTHM, low																								
	HAA5, high																								
	HAA5, base	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	HAA5, low																								
Exposure to pathogens	High	Governed by model parameters																							
	Base																								
	Low																								
Run ID	Unique system number	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64

2.4.13. Subtask 1.6 – Integration and representation of results

The objective of this subtask is to develop a set of intuitive, well-edited figures presenting a set of key results from the base case and disinfection alternative model runs and economic accounts appropriate for engaging decision-makers. This subtask involves the integration of results for both the base case and disinfection alternatives to compare technologies and highlight key system aspects. To accomplish this subtask, the Contractor shall engage in discussion with the EPA Work Assignment Manager, select key results and sources of variability to be presented based on the discussion, formulate an appropriate means of conveying key information, develop a draft set of figures for EPA review, and revise figures according to review comments received from the Work Assignment Manager. This work will involve performing additional spreadsheet calculations and data manipulations to combine economic and life cycle impact results for both the base case and disinfection alternative systems and to draw out important features of the data. The final set of results shall reflect key aspects of the analysis, which will be expanded on in the discussion provided in the manuscript produced in the subsequent subtask.

Milestones: (M-2.6.1) **Draft key figures for comparison of base case and disinfection alternatives** – key figures, provided electronically in an Excel or similar file for review

Deliverables: (D-2.6.2) **Key figures for comparison of base case and disinfection alternatives (revised)** – revised version of the draft key figures (M-2.6.1) modified in response to comments

2.4.14. Subtask 2.7 – Documentation and manuscript writing: model development and LCA results for comparison of base case and alternative disinfection technologies

The objective of this subtask is to document the model and results produced in this Task in a manuscript and associated supporting information in a format appropriate for submission to a scientific journal. To accomplish this, the Contractor shall: (a) write sections of a manuscript presenting model development and LCA and economic results for comparison of base case and alternative disinfection technologies, (b) respond to comments provided through an internal peer-review process coordinated by the EPA Work Assignment Manager, (c) prepare and format materials in accordance with the specifications for the journal agreed upon through discussion with the EPA Work Assignment Manager, and (d) assist EPA in responding to comments received from the journal peer-reviewers in coordination with the EPA Work Assignment Manager. It is anticipated the EPA Work Assignment Manager and/or (a) member(s) of the EPA Technical Team will provide significant input to the manuscript and serve as (a) co-author(s).

This manuscript shall contain at minimum the following sections: abstract, literature review, method, results, sensitivity analysis, and discussion and shall be accompanied by a document containing supporting information (SI). The abstract shall highlight key points from the article focusing on key quantitative insights. The literature review shall provide context for the work performed within this Task including presenting key findings from previous studies, placing this study within the context of prior studies, and describing previous studies and data collection efforts, which were utilized in the development of the LCA model developed within this

Statement of Work. The method shall include the system diagrams, descriptions of the unit processes that make up the systems, a brief description of the impact assessment methods used in the model, a brief description of the economic accounts and data sources, and references to more detailed information provided in the SI. The results shall include selected key figures as well as reference to more detailed results provided in the SI. Similarly, the sensitivity analysis shall provide a description of the results of the sensitivity analysis, selected figures highlighting key sensitivities, and references to more detailed sensitivity results provided in the SI. The discussion shall address the interpretation of results, strengths, and limitations of the results and approach, implications of results for decision-making, and next steps for further investigation of questions that arise in the course of this work. The SI shall include more detailed quantitative information necessary for understanding the model, other results not included in the main manuscript, and text documenting the supporting information.

- Milestones: (M-2.7.1) **Draft Task 2 manuscript**– draft version of the manuscript for project internal peer-review
- (M-2.7.2) **Response to peer-review of Task 2 manuscript** – including a revised version of the submitted manuscript (D-2.7.1) modified to address comments received through external peer-review and a Word file containing itemized responses to reviewer comments
- Deliverables: (D-2.7.1) **Task 2 manuscript: Model Development and LCA Results for Drinking Water Treatment Options (revised and formatted)** – revised version of the draft manuscript (M-2.7.1) formatted for submission to an appropriate peer-reviewed, scientific journal

Task 3 - LCA and economic assessment of point-of-use disinfection at hospitals and care facilities

The key questions to be addressed in this task are:

- (1) What are the impacts associated with the point-of-use treatment and use of drinking water for each of the alternatives?
- (2) What is the relationship between differences in impact results for specified flows of interest?
- (3) How do the results differ for an average adult, a child, and an immunocompromised adult?
- (4) What is the effect of plausible parameter variability? What parameters associated with uncertainty in residence time requirements have the greatest effect on net greenhouse gas and human health impact results? How does varying estimates of exposure to pathogens in drinking water effect their contribution to total human health results for immunocompromised adults?

2.4.15. Subtask 3.1 - Develop a set of system descriptions

The objective of this subtask is to develop a set of generalized system descriptions representative of individual faucet, point-of-use water treatment and the benefits for drinking water consumption by children and immune-compromised individuals. Four individual faucet, point-of-use treatment alternatives are considered: granular activated carbon (GAC), conventional UV and GAC, LED UV and GAC, and plasma bead UV and GAC.

The systems descriptions developed in this subtask relate to the broader drinking water life cycle presented in Figure 1 in they could be inserted between *distribution* and *drinking water use* to represent alternative life cycle pathways for drinking water. The system descriptions developed within this subtask serve as a framework for the model to be developed in the subtasks, which follow. The addition of *treatment at point of use* and the modification of *drinking water use* are anticipated to be the primary components of the overall drinking water life cycle effected by the options considered here.

The point of use treatment options is primarily represented by the subsystems included in the list that follows. In this subtask, the Contractor shall provide additional details underlying the systems listed below and define the reference flows between processes. Each of the processes shall be accompanied by the associated inputs and infrastructure components.

- (1) **Treatment at point-of-use with granular activated carbon (GAC), operation** – operation of an individual faucet, point-of-use treatment unit using GAC as the treatment agent.
- (2) **Granular activated carbon point-of-use treatment unit production** – a reference supply chain representing production of an individual faucet, point-of-use GAC treatment unit.
- (3) **Treatment at point-of-use with conventional UV and GAC, operation** – operation of an individual faucet, point-of-use treatment unit using conventional UV and GAC as the treatment agents.
- (4) **Conventional UV and GAC point-of-use treatment unit production** – a reference supply chain representing production of an individual faucet, point-of-use conventional UV and GAC treatment unit.
- (5) **Treatment at point-of-use with ultrafiltration** – operation of an individual faucet, point-of-use treatment unit using membrane ultrafiltration.
- (6) **Ultrafiltration treatment unit production** – a reference supply chain representing production of an individual faucet, point-of-use ultrafiltration treatment unit.
- (7) **Treatment at point-of-use with LED UV and GAC, operation** – operation of an individual faucet, point-of-use treatment unit using LED UV and GAC as the treatment agents.
- (8) **LED UV point-of-use treatment unit production** – a reference supply chain representing production of an individual faucet, point-of-use LED UV and GAC treatment unit.
- (9) **Treatment at point-of-use with plasma bead UV and GAC, operation** – operation of an individual faucet, point-of-use treatment unit using plasma bead UV and GAC as the treatment agents.
- (10) **Plasma bead UV point-of-use treatment unit production** – a reference supply chain representing production of an individual faucet, point-of-use plasma bead UV and GAC treatment unit.
- (11) **Drinking water use** – descriptions of the changes in exposure to disinfection by-products and pathogens associated with the implementation of each alternative disinfection approach.

For each description the Contractor shall: (a) produce a set of system diagrams and simplified versions of the system diagrams for inclusion in presentations using MS Visio or similar software to be agreed upon with the Work Assignment Manager and (b) write descriptions of: (i) the systems to be analyzed including descriptions of relevant technosphere and natural processes, (ii) the impacts to be tracked and their relevance to the system, (iii) a list of key parameters and initial hypotheses regarding their relative importance for results in key impact categories (i.e., global warming potential), and (iv) the data sources to be used and the transformations necessary to incorporate them into the model. These descriptions serve as a basis for prioritizing and allocating time to data collection and model development activities.

- Milestones:
- (M-3.1.1) **Draft system description** – draft version of the system descriptions in the form of a Microsoft Word file including figures pasted from Visio and associated descriptions for review
 - (M-3.1.2) **Revised system description** – modified version of the system description (M-3.1.1) with all review comments addressed
 - (M-3.1.3) **Revised Visio diagrams** – a zip file containing the diagrams in their original editable format

2.4.16. Subtask 3.2 – Data Collection: Collect and process data from datasets, literature review, secondary sources, and through identifying and engaging partners to produce life cycle inventory unit process datasets for use in modeling

The objective of this subtask is to compile the information needed to develop LCA models for the point-of-use treatment options in the subsequent subtasks. To accomplish this, the Contractor shall: (a) collect the necessary data from relevant datasets, literature review, secondary sources, and through coordinating with partners via phone calls and email exchanges; (b) organize a data archive including clearly documented original data and transformations; and (c) process data from its received format into unit process data consistent with use in an LCA model and including relevant metadata. The guidelines for carrying out this subtask are the same as those governing subtask 1.2.

Data for these technologies shall be obtained through literature review and through interacting with EPA partner organizations involved in their development. The partner organizations associated with the LED UV and plasma bead UV technologies are Aquionics, Inc. and Imaging Systems Technologies respectively. Because these are the same partners identified in subtask 2.2, it would be most efficient to engage these partners in providing data for the municipal-scale and point-of-use treatment systems simultaneously. In addition, the EPA Technical Team guiding this LCA effort has been provided some funding to conduct directed lab tests deemed necessary to provide key inputs to the LCA model.

As in subtask 1.2, the previously developed system descriptions will serve as the basis for unit process development with the goal of establishing a comprehensive model form capable including parameters governing individual unit processes. Efforts to assign values to parameters and flows will be conducted on an iterative basis with the goal being to establish a base set of values and work from there to improve upon the base set according to the results of model beta runs. The Contractor shall use parameters to govern the inputs and outputs of unit processes to account for a range of values for residence time and pathogens including *Cryptosporidium* &

Giardia oocysts, *Legionella*, adenoviruses and enteroviruses.. During the course of this subtask, the Contractor shall review the system descriptions with the Work Assignment Manager and according to the findings establish an approach to unit process and model development.

To complete this subtask, Contractor shall: (a) produce the necessary additional life cycle inventory unit processes using a template including files in Microsoft Word and Excel format and (b) import unit process data into the openLCA software package.

The requirements and guidance provided in subtask 1.2 regarding provision of data to EPA, documentation format, allocation of time, the use of background datasets apply to this subtask.

- Milestones: (M-3.2.1) **Draft Unit Processes** – a zip file or similar containing unit processes used in this Statement of Work provided for review. Unit processes shall be provided in the form of MS Word and Excel files as described above.
- (M-3.2.2) **Electronic data collection archive** – a zip file or similar containing the results of data collection in the form of PDF and other files organized in labeled folders
- Deliverables: (D-3.2.1) **Unit Processes (revised)** – a zip file or similar containing modified versions of the draft unit processes (M-3.2.1) following incorporation of review comments

2.4.17. Subtask 3.3 – Collect and process economic data for point-of-use treatment alternatives

The objective of this subtask is to develop an account of the costs of point-of-use DWT using the four alternative technologies. The product of this work will be a series of spreadsheets describing the production, operation, and maintenance costs for the point-of-use treatment units. This account shall be consistent with the economic accounts developed under subtask 1.3. Cost data will be collected from project partners using a format similar to the one developed under Subtask 1.3 and supplemented with data from the literature where necessary. The electronic files associated with data collection and literature search shall be organized and saved in an electronic archive to be provided to EPA for future reference. All data collected shall be provided to EPA and disseminated publicly by EPA at its discretion.

- Milestones: (M-3.3.1) **Draft economic account** – a series of spreadsheets containing accounts for infrastructure components, construction processes, operation and maintenance processes, and key infrastructure requirements associated with maintenance. Unit processes shall be provided in the form of Excel files with accompanying documentation.
- (M-3.3.2) **Electronic data collection archive** – a zip file or similar containing the results of data collection in the form of PDF and other files organized in labeled folders
- Deliverables: (D-3.3.1) **Economic account (revised)** – a zip file or similar containing modified versions of the economic account (M-3.3.1) following incorporation of review comments

2.4.18. Subtask 3.4 – Incorporate unit processes and perform the reference set of LCA model runs for point-of-use treatment alternatives

The objectives of this subtask are (1) to ensure the unit processes are properly incorporated into the LCA model and then (2) to use the model to generate results for the a reference set of model runs for point-of-use alternatives to address the questions posed in the first section of the Task 3 description and additional questions identified in the course of the work as agreed upon with the EPA Work Assignment Manager. As in the previously described tasks, the LCA model shall be: (a) developed within an appropriate LCA software platform which allows for full conversion to the open LCA software platform by EPA, (b) based on transparent, public or commercially-available background data, and (c) submitted to EPA for quality assurance and review of unit process data at appropriate points in the project timeline to allow for the Contractor to incorporate EPA-provided comments/revisions.

A list of anticipated reference set of model runs for disinfection alternatives are detailed in the columns on the left in Table 4. Sensitivity analysis runs are presented on the right side of Table 4 and described in the subsequent subtask. The runs identified in Table 4 provide guidance regarding the level of effort anticipated associated with generating model results. If during the course of carrying out this Task it is determined that modifications to this list are warranted, these modifications shall be made in such a way the overall level of effort required to carry out this Task is not affected.

Following a review of preliminary results by the EPA Work Assignment Manager, the results shall be documented in tabular form in an Excel or similar spreadsheet file. This documentation shall include sufficient commenting to identify the systems and parameters represented by each run and shall include a breakdown of results by impact and DWT process/life cycle stage.

- Milestones: (M-3.4.1) **Results for reference set of model runs for disinfection alternatives**
– tabular results for the model runs and sensitivity analysis provided electronically in an Excel or similar file
- Deliverables: (D-3.4.1) **Updated life cycle inventory database** - a file exported from the LCA software such as a GaBi exchange file (or standard LCA data exchange format such as ILCD or Ecospol) and provided electronically

2.4.19. Subtask 3.5 - Sensitivity analysis and optional additional uncertainty analysis

The Contractor shall conduct a sensitivity analysis to understand the effect of variability in key parameters on the results of the LCA models for point-of-use treatment alternatives. Key parameters shall be identified in consultation with the EPA Work Assignment Manager. The effect of variability shall be assessed parametrically and the results presented in the form of appropriate tables or figures. To provide a clear basis for estimating the level of effort required, a set of model runs anticipated to be evaluated is provided in the columns on the right of Table 4.

Sensitivity analysis for point-of-use treatment alternatives, as envisioned prior to beginning this work, involves assessing variation of residence time / UV exposure time and exposure to pathogens. Tracked pathogens include *Cryptosporidium* & *Giardia* oocysts, *Legionella*, adenoviruses and enteroviruses.. For the purposes of this sensitivity analysis, model runs will be

performed for representative low and high cases for model parameters as detailed in Table 4. If during the course of carrying out this Task it is determined that different model runs are warranted, these modifications shall be made in such a way the overall level of effort required to carry out this Task is not affected.

Milestones: (M-3.5.1) **Sensitivity analysis results for point-of-use alternatives** – tabular results for the sensitivity analysis model runs provided electronically in an Excel or similar file

Table 4. Reference and sensitivity model runs for disinfection alternatives.

		Options for POU treatment, base case						Options for POU treatment, immuno-compromised adult						Options for POU treatment, child						Sensitivity analysis for options for POU treatment																	
		Null/ GAC		μ		UV		Null/ GAC		μ		UV		Null/ GAC		μ		UV		Conv.		μ		LED		Plasma bead											
		No further treatment		Microfiltration		Conv. UV + GAC		LED UV + GAC		Plasma bead UV + GAC		No further treatment		Microfiltration		Conv. UV + GAC		LED UV + GAC		Plasma bead UV + GAC		Conv. UV + GAC, low RT		Conv. UV + GAC, high RT		Microfiltration, low degradation rate		Microfiltration, high degradation rate		LED UV + GAC, low RT		LED UV + GAC, high RT		Plasma bead UV + GAC, low RT		Plasma bead UV + GAC, high RT	
Drinking water acquisition	Surface water	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	Undergr. aquifer																																				
Pre-disinfection	Pre-filtration	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	Flocculation/sedimentation	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	Filtration (sand & anthracite)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	GAC sorption	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	Microfiltration																																				
	Conditioning	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Disinfection	Gaseous chlorine	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	Conventional UV																																				
	LED UV																																				
	Plasma bead UV																																				
	Ferrate																																				
	Hypochlorite	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Distribution	Base case infrastructure	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Point-of-use treatment	Conventional UV				X						X						X				X	X															
	Microfiltration			X						X						X							X	X													
	LED UV					X					X						X								X	X											
	Plasma bead UV					X					X						X																X	X			
	Granular activated carbon		X		X	X	X		X		X	X	X		X		X	X	X	X	X				X	X	X			X	X	X	X	X			
	Drinking water use	Healthy adult	X	X	X	X	X	X			X					X																					
	Child													X	X		X	X	X																		
	Immunocompromised adult							X	X		X	X	X				X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Impacts tracked	Full suite of impacts	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																		
	Human health																				X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	Primary energy demand																				X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	Global warming potential																																				
Monetary values tracked	Infrastructure	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	Operation & maintenance	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	Externality valuation	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																	
Multi-attribute metrics tracked	Energy	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																		
	Ecological footprint	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																		
Source water characteristics	Organic matter, high																																				
	Organic matter, base	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	Organic matter, low																																				
	Sediment, high																																				
	Sediment, base	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	Sediment, low																																				
	Iron, high																																				
	Iron, base	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	Iron, low													</																							

2.4.20. Subtask 3.6 – Integration and representation of results

The objective of this subtask is to develop a set of intuitive, well-edited figures presenting a set of key results from the point-of-use treatment alternative model runs and economic accounts appropriate for engaging decision-makers. This subtask involves the integration of point-of-use treatment results with the base case municipal DWT (a) to place POU results in context, (b) to allow for comparing alternative POU technologies, and (c) to highlight key system aspects.

To accomplish this subtask, the Contractor shall (a) engage in discussion with the EPA Work Assignment Manager, (b) select key results and sources of variability to be presented based on the discussion, (c) formulate an appropriate means of conveying key information, (d) develop a draft set of figures for EPA review, and (e) revise figures according to review comments received from the Work Assignment Manager. This work will involve performing additional spreadsheet calculations and data manipulations to combine economic and life cycle impact results for both the base case and alternative POU systems and to draw out important features of the data. The final set of results shall reflect key aspects of the analysis, which will be expanded on in the discussion provided in the manuscript produced within the subsequent subtask.

Milestones: (M-3.6.1) **Draft key figures for comparison of base case and disinfection alternatives** – key figures, provided electronically in an Excel or similar file for review

Deliverables: (D-3.6.2) **Key figures for comparison of base case and disinfection alternatives (revised)** – revised version of the draft key figures modified in response to comments

2.4.21. Subtask 3.7 – Documentation and manuscript writing: model development and LCA results for comparison of point-of-use treatment alternatives

The objective of this subtask is to document the model and results produced in this Task in a manuscript and associated supporting information in a format appropriate for submission to a scientific journal. To accomplish this, the Contractor shall: (a) write sections of a manuscript presenting model development and LCA and economic results for electricity and heat from biomass, (b) respond to comments provided through an internal peer-review process coordinated by the EPA Work Assignment Manager, (c) prepare and format materials in accordance with the specifications for the journal agreed upon through discussion with the EPA Work Assignment Manager, and (d) assist EPA in responding to comments received from the journal peer-reviewers in coordination with the EPA Work Assignment Manager. While this Task has been written in a way that it could be successfully carried out entirely by the Contractor, it is anticipated the EPA Work Assignment Manager or a member of the EPA Technical Team will serve as a co-author and will provide written input to the manuscript.

This manuscript shall contain at minimum the following sections: abstract, literature review, method, results, sensitivity analysis, and discussion and shall be accompanied by a document containing supporting information (SI). The abstract shall highlight key points from the article focusing on key quantitative insights. The literature review shall provide context for the work performed within this Task including presenting key findings from previous studies, placing this study within the context of prior studies, and describing previous studies and data collection efforts, which were utilized in the development of the LCA model developed within this

Statement of Work. The method shall include the system diagrams, descriptions of the unit processes that make up the systems, a brief description of the impact assessment methods used in the model, a brief description of the economic accounts and data sources, and references to more detailed information provided in the SI. The results shall include selected key figures as well as reference to more detailed results provided in the SI. Similarly, the sensitivity analysis shall provide a description of the sensitivity analysis, selected figures, and references to more detailed sensitivity results provided in the SI. The discussion shall address the interpretation of results, strengths, and limitations of the results and approach, implications of results for decision-making, and next steps for further investigation of questions that arise in the course of this work. The SI shall include more detailed quantitative information necessary for understanding the model, other results produced in this Task not included in the main manuscript, and text documenting the supporting information.

- Milestones: (M-3.7.1) **Draft Task 3 manuscript**– draft version of the manuscript for project internal peer-review
- (M-3.7.2) **Response to peer-review of Task 3 manuscript** – including a revised version of the submitted manuscript (D-3.7.1) modified to address comments received through external peer-review and a Word file containing itemized responses to reviewer comments
- Deliverables: (D-3.7.1) **Task 3 manuscript: Model development and LCA results for point-of-use drinking water treatment options (revised and formatted)** – revised version of the draft manuscript (M-3.7.1) formatted for submission to an appropriate peer-reviewed, scientific journal

2.5. Task 4 –LCA and economic assessment of base case wastewater management

The objective of this task is to establish a flexible LCA model and associated economic accounts describing a base case for wastewater collection, treatment, waste management, and treated water release.

The key questions to be addressed under this task are:

- (6) What are the net life cycle impacts associated with the collection and treatment of municipal wastewater?
- (7) What are the contributions of each life cycle stage to the net result for each impact category? What are the contributions of each step in the wastewater management system?
- (8) What are the contributions of specific environmental releases to the net result for each technology and impact category?
- (9) What is the effect of plausible parameter variability? What parameters associated with wastewater characteristics have the greatest effect on net greenhouse gas and human health impact results?

2.5.1. Subtask 4.1 - Develop a set of system descriptions for a reference model

The objective of this subtask is to develop a set of generalized system descriptions representative of a municipal WWT system. For the purposes of this project, the Metropolitan Sewer District of Greater Cincinnati's Mill Creek Wastewater Treatment Plant will be adopted as a point of

reference. The system descriptions developed within this subtask serve as a framework for the model to be developed in the subtasks, which follow. The reference systems are meant to be general enough they could be used to describe variation of wastewater characteristics and operational specifications and modular such the system descriptions could be rearranged to represent different WWT pathways.

Figure 2 contains the preliminary system description that will be used for this work. This system is comprised of a series of WWT and other life cycle stages including the list that follows. In this subtask, the Contractor shall provide additional details underlying the systems listed below and define the reference flows between processes. Each of the processes shall be accompanied by the associated infrastructure components.

- (1) **Wastewater collection** – including wastewater collection at households and transport by sewer to the WWT facility and inclusion of consideration for overflow associated with high flow events.
- (2) **Pre-treatment** – including screening, grit removal, equalization basins, and fat and grease skimming.
- (3) **Primary sedimentation** – including sedimentation in pre-settling basins, mechanical scraping, and mechanical skimming of grease and oil.
- (4) **Activated sludge and ammonium-oxidation** – considering a conventional aerobic process using activated sludge secondary treatment and including the aeration unit and all associated energy use for ammonium-oxidation to nitrate using nitrifying bacteria in the activated sludge.
- (5) **Secondary sedimentation** – consisting of settling of biological flocculant and mechanical scraping.
- (6) **Filtration** – consisting of sand filtration to remove residual suspended matter
- (7) **Denitrification** – denitrification of nitrate to gaseous nitrogen with anoxic bacterial species facilitated by methanol as the carbon source.
- (8) **Chlorine disinfection and dechlorination** – effluent disinfection using chlorine gas as the disinfectant including consideration of concentration-time requirement and its effect under increased flow rate events.
- (9) **Conventional UV disinfection** – effluent disinfection using a conventional UV system disinfecting agent including consideration of UV-fluence requirement and its reduced efficacy with increased turbidity during rain events.
- (10) **Sludge digesting** – including mesophilic anaerobic digestion.
- (11) **Biogas collection and flaring** - collection of methane from sludge treatment, delivery to a combustion unit providing heat to the mesophilic digester, and flaring of excess gas.
- (12) **Sludge dewatering** – using the MSDGC as a reference.
- (13) **Landfilling of sludge and fats, oils, and greases** – including transportation of sludge, landfill operation, and an estimate of emissions from landfilled sludge.
- (14) **Environmental behavior of effluent** - between release and DWT intake including processes describing the effect of effluent on the source water feeding downstream DWT and a rough estimation of beach closure and health effects associated with exposed swimmers.

For each description the Contractor shall: (a) produce a set of system diagrams and simplified versions of the system diagrams for inclusion in presentations using MS Visio or similar software to be agreed upon with the Work Assignment Manager and (b) write descriptions of: (i) the systems to be analyzed including descriptions of relevant technosphere and natural processes, (ii) the impacts to be tracked and their relevance to the system, (iii) a list of key parameters and initial hypotheses regarding their relative importance for results in key impact categories (i.e., global warming potential), and (iv) the data sources to be used and the transformations necessary to incorporate them into the model. These descriptions serve as a basis for prioritizing and allocating time to data collection and model development activities.

- Milestones:
- (M-4.1.1) **Draft system description** – draft version of the system descriptions in the form of a Microsoft Word file including figures pasted from Visio and associated descriptions for review
 - (M-4.1.2) **Revised system description** – modified version of the system description (M-4.1.1) with all review comments addressed
 - (M-4.1.3) **Revised Visio diagrams** – a zip file containing the diagrams in their original editable format

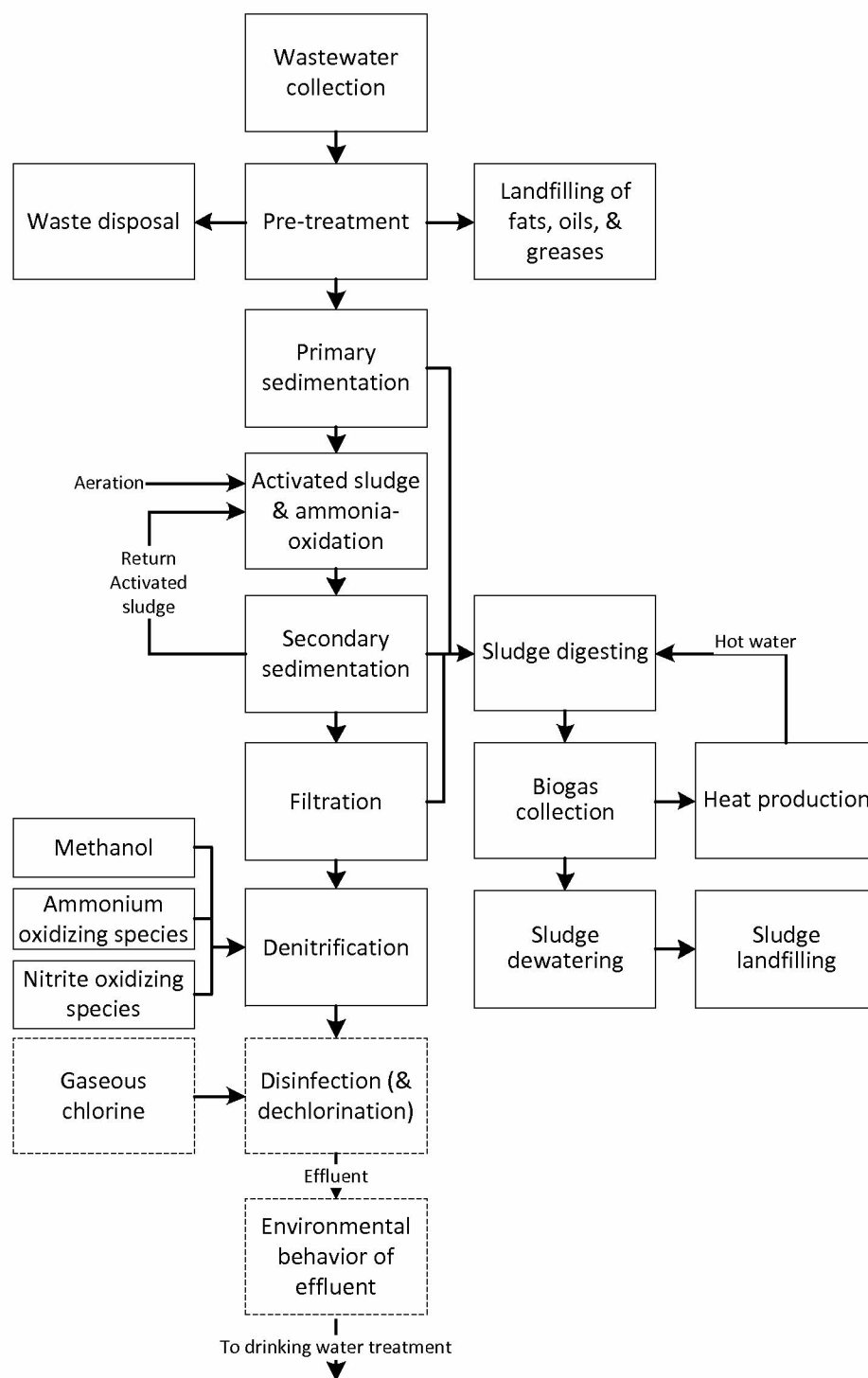


Figure 2. System description for base case wastewater treatment system representative of the Metropolitan Sewer District of Greater Cincinnati's Mill Creek Wastewater Treatment Plant. Dotted boxes represent processes, which are modified to represent disinfection alternatives.

2.5.2. Subtask 4.2 – Data collection and unit process development: collect and process data from datasets, literature review, secondary sources, and through identifying and engaging partners to produce life cycle inventory unit process datasets for use in modeling

The Contractor shall: (a) collect the necessary data from relevant datasets, literature review, secondary sources, and through coordinating with partners via phone calls and email exchanges; (b) organize a data archive including clearly documented original data and transformations; and (c) process data from its received format into unit process data consistent with use in an LCA model and including relevant metadata. The guidelines for carrying out this subtask are the same as those governing subtask 1.2. EPA has engaged the Metropolitan Sewer District of Greater Cincinnati (MSDGC) in this work. The Contractor shall correspond with MSDGC contacts provided by EPA to obtain relevant data based on their process.

Figure 2 together with the associated system descriptions will serve as the basis for unit process development. Unit processes will be developed with the understanding that establishing a comprehensive model form capable including parameters governing individual unit processes is the primary objective. Efforts to assign values to parameters and flows will be conducted on an iterative basis with the goal being to establish a base set of values and work from there to improve upon the base set according to the results of (a) model beta run(s). During the course of this Task, the Contractor shall review the system descriptions with the Work Assignment Manager and according to the findings establish an approach to unit process and model development.

The Contractor shall use parameters to govern the inputs and outputs of unit processes to account for a range of values for organic matter concentration, water temperature, and concentration-time for chlorine disinfection. This Task shall be executed efficiently through the modification of unit processes created for DWT related to chlorine gas production, chlorine gas disinfection processes, conventional UV system, and conventional UV operation. The LCA model developed here will be combined in series with the DWT model such the characteristics of the treated effluent will feed back into the DWT system and the downstream consumption. Setting up the model in this way allow estimation of human health effects associated with exposure to components of WWT effluent such as disinfectant by-products and other contaminants. The focus in this work will be on those effluent constituents most affected by the selection of chlorine gas, conventional UV, and eventually peracetic acid disinfection alternatives.

The Contractor shall: (a) produce the necessary additional life cycle inventory unit processes using a template including files in Microsoft Word and Excel format and (b) import unit process data into the openLCA software package.

All LCA unit process data developed within the context of this agreement will be provided by the Contractor to EPA in the form of Microsoft Word and Excel documentation using templates provided by EPA. An example of the Microsoft Word template is provided in an Appendix. The goal of the data template is to capture the original data and transformations used to develop unit processes in a format, which can be traced back by a knowledgeable practitioner and efficiently updated by others in follow on work. However, it is the intention that data collection and documentation should be performed efficiently considering the limited time and resources.

While the goal of this work is to establish a fully transparent set of LCA unit processes, it is clear that background LCA databases such as EcoInvent, US LCI, and/or GaBi should be used to allow for efficient estimation of upstream impacts. To the extent that existing LCA background data are used to provide results for upstream impacts, these data shall come from a dataset that has been quality checked and which is publicly available at a reasonable cost (i.e. EcoInvent). The Contractor shall alert EPA to unit process data already existing within unit processes developed prior to this agreement before incorporating them in the LCA models developed under this agreement.

- Milestones: (M-4.2.1) **Draft Unit Processes** – a zip file or similar containing unit processes used in this Statement of Work provided for review. Unit processes shall be provided in the form of MS Word and Excel files as described above.
- (M-4.2.2) **Electronic data collection archive** – a zip file or similar containing the results of data collection in the form of PDF and other files organized in labeled folders
- Deliverables: (D-4.2.1) **Unit Processes (revised)** – a zip file or similar containing modified versions of the draft unit processes (M-4.2.1) following incorporation of review comments

2.5.3. Subtask 4.3 – Collect and process economic data for base case wastewater treatment

The objective of this subtask is to develop an account of the economic structure of WWT. The product of this work will be a series of spreadsheets describing the infrastructure costs for the base case WWT facility and the operation and maintenance costs associated with each of the WWT processes. To the extent possible, these accounts will include information provided by the MSDGC. Where data are not available from MSDGC, gaps will be filled with values from the literature and best estimates using proxy values and/or expert judgment when better values are not available. These economic accounts shall parallel the life cycle inventory through matching life cycle inventory input and output names with those associated with the cost data. In cases where additional economic details are available, inputs and outputs shall be decomposed into subcomponents. , additional information will be required to balance the economic accounts such as salaries, purchased services not represented in the life cycle inventory, and interest paid on borrowed funds. The account for infrastructure shall include key facility components, which, together with other construction and management costs, are representative of the initial cost of the DWT facility. The account for operation and maintenance shall be broken out into each of the DWT and distribution processes described in this Task. When necessary, infrastructure accounts will be provided for key maintenance inputs.

An initial step in this work shall be to develop a framework for collecting cost information based on the life cycle inventory processes. This format will be shared with the MSDGC and other project partners as deemed appropriate to collect the required data. When supplemental data are collected from the literature, the associated files shall be organized and saved in an electronic archive to be provided to EPA for future reference. No confidential business information is anticipated to be collected in this subtask and thus no non-disclosure agreements will be

executed. All data collected shall be provided to EPA and disseminated publicly by EPA at its discretion.

- Milestones: (M-4.3.1) **Draft economic account** – a series of spreadsheets containing accounts for infrastructure components, construction processes, operation and maintenance processes, and key infrastructure requirements associated with maintenance. Unit processes shall be provided in the form of Excel files with accompanying documentation.
- (M-4.3.2) **Electronic data collection archive** – a zip file or similar containing the results of data collection in the form of PDF and other files organized in labeled folders
- Deliverables: (D-4.3.1) **Economic account (revised)** – a zip file or similar containing modified versions of the economic account (M-2.1) following incorporation of review comments

2.5.4. Subtask 4.4 – Incorporate unit processes and perform a reference set of model runs for base-case wastewater treatment

The objectives of this subtask are (1) to ensure the unit processes developed in subtask 4.3 are properly incorporated into the LCA model and then (2) to use the model to generate results for base case WWT to address the questions posed in the first section of this task description and additional questions identified in the course of the work as agreed upon with the EPA Work Assignment Manager. As in the previously described tasks, the LCA model shall be: (a) developed within an appropriate LCA software platform which allows for full conversion to the open LCA software platform by EPA, (b) based on transparent, public or commercially-available background data, and (c) submitted to EPA for quality assurance and review of unit process data at appropriate points in the project timeline to allow for the Contractor to incorporate EPA-provided comments/revisions.

Only a single model run is anticipated to represent the base case WWT. The components of the base case LCA model are presented toward the left in Tables 5a and 5b. Sensitivity analysis runs are presented on the right side of Tables 5a and 5b and described in a subsequent subtask.

Following a review of preliminary results by the EPA Work Assignment Manager, the results shall be documented in tabular form in an Excel or similar spreadsheet file. This documentation shall include sufficient commenting to identify systems and parameters represented and shall include a breakdown of results by impact and WWT process/life cycle stage.

- Milestones: (M-4.4.1) **Results for reference set of model runs for base case wastewater treatment** – tabular results for the model runs and the sensitivity analysis provided electronically in an Excel or similar file
- Deliverables: (D-4.4.1) **Life cycle inventory database** - a file exported from the LCA software such as a GaBi exchange file (or standard LCA data exchange format such as ILCD or Ecospol) and provided electronically

[illegible]

Table 5b. Reference model runs and sensitivity analysis to be evaluated under Task 4 for base case wastewater treatment using chlorine or conventional UV and Task 5 for the peracetic acid disinfection alternative (continued).

[illegible]

2.5.5. Subtask 4.5 - Sensitivity analysis and optional additional uncertainty analysis

The objective of this subtask is to explore the effect of modeling choices and variability. The Contractor shall conduct a sensitivity analysis to understand the effect of variability in key parameters on the results of the LCA model. Key parameters shall be identified in consultation with the EPA Work Assignment Manager. The effect of variability shall be assessed parametrically and the results presented in the form of appropriate tables or figures. To provide a clear basis for estimating the level of effort required, a set of model runs anticipated to be evaluated is provided in the columns on the right of Tables 5a and 5b. Note the sensitivity analysis model runs described in Table 5 are repeated for the two base case WWT options (and again for the peracetic acid alternative in connection with Task 5). For the purposes of this sensitivity analysis, model runs will be performed for representative low and high cases for model parameters as detailed in Table 5. While these sensitivity analyses may be generated as individual model runs, there may be a creative means to accomplish this which is more efficient, for example by manipulating results for individual stages in Excel. A final approach to producing these results efficiently shall be proposed by the Contractor and decided in consultation with the EPA Work Assignment Manager.

If during the course of carrying out this Task it is determined that modifications to the model runs represented in Table 5 are warranted, these modifications shall be made in such a way the overall level of effort required to carry out this Task is not effected.

Milestones: (M-4.5.2) **Results for base case wastewater treatment sensitivity analysis** – tabular results for the sensitivity analysis model runs provided electronically in an Excel or similar file

2.5.6. Subtask 4.6 - Representation of results

The objective of this subtask is to develop a set of intuitive, well-edited figures presenting a set of key results from the model runs and economic accounts appropriate for engaging decision-makers. To accomplish this subtask, the Contractor shall engage in discussion with the EPA Work Assignment Manager, select key results and key sources of variability to be presented based on the discussion, develop a draft set of figures for EPA review, and revise figures according to review comments received from the Work Assignment Manager. This work will involve performing additional spreadsheet calculations and data manipulations to combine economic and life cycle impact results and to draw out important features of the data. The final set of results shall reflect key aspects of the analysis, which will be expanded on in the discussion provided in the manuscript produced in a subsequent subtask.

Milestones: (M-4.6.1) **Draft key figures for the base case** – key figures provided electronically in an Excel or similar file for review

Deliverables: (D-4.6.2) **Key figures for the base case (revised)** – revised version of the draft key figures (M-4.6.1) modified in response to comments

2.5.7. Subtask 4.7- Documentation and manuscript writing: model development and LCA results for the base case drinking water treatment systems

The objective of this subtask is to document the model and results produced in this Task in a manuscript and associated supporting information in a format appropriate for submission to a scientific journal. To accomplish this, the Contractor shall: (a) write sections of a manuscript presenting model development and LCA and economic results for the base case DWT systems, (b) respond to comments provided through an internal peer-review process coordinated by the EPA Work Assignment Manager, (c) prepare and format materials in accordance with the specifications for the journal agreed upon through discussion with the EPA Work Assignment Manager, and (d) assist EPA in responding to comments received from the journal peer-reviewers in coordination with the EPA Work Assignment Manager. It is anticipated the EPA Work Assignment Manager and/or (a) member(s) of the EPA Technical Team will provide significant input to the manuscript and serve as (a) co-author(s).

This manuscript shall contain at minimum the following sections: abstract, literature review, method, results, sensitivity analysis, and discussion and shall be accompanied by a document containing supporting information (SI). The abstract shall highlight key points from the article focusing on key quantitative insights. The literature review shall provide context for this work including a brief summary of the work performed under this Task. It shall include key findings from other previous studies, place this study within the context of these prior studies, and describe data and transformations, which were utilized in the development of the LCA model developed within this Statement of Work. The method shall include the system diagrams, descriptions of the unit processes that make up the systems, a brief description of the impact assessment methods used in the model (or reference to a previous manuscript), a description of the impact assessment methods used to quantify risk associated with exposure of swimmers to pathogens, a brief description of the economic accounts and data sources, and references to more detailed information provided in the supporting information (SI). The results shall include selected figures as well as reference to more detailed results provided in the SI. Similarly, the sensitivity analysis shall provide a description of the analysis, selected figures associated with the sensitivity analysis, and references to more detailed sensitivity results provided in the SI. The discussion shall address the interpretation of results, strengths, and limitations of the results and approach, implications of results for decision-making, and next steps for further investigation of questions that arise in the course of this work. The SI shall include more detailed quantitative information necessary for understanding the model, other results not included in the main manuscript, and the associated text needed for documentation.

- Milestones: (M-4.7.1) **Draft Task 4 manuscript** – draft version of the manuscript for project internal peer-review
- (M-4.7.2) **Response to peer-review of Task 4 manuscript** – including a revised version of the submitted manuscript (D-4.7.1) modified to address comments received through external peer-review and a Word file containing itemized responses to reviewer comments
- Deliverables: (D-4.7.1) **Task 4 manuscript: Model Development and LCA Results for Drinking Water Treatment Options (revised and formatted)** – revised version of the draft manuscript (M-4.7.1) formatted for submission to an appropriate peer-reviewed, scientific journal

2.6. Task 5 – LCA and economic comparison of base-case and peracetic acid waste water treatment

The objective of this task is to establish a flexible LCA model and associated economic accounts describing alternative disinfection methods within the context of the full wastewater life cycle. This Task builds upon the base case models developed in Tasks 1 and 4.

The key questions to be addressed in this task are:

- (1) What is the net life cycle impacts associated with the use of peracetic acid for WWT and how do they compare with those of the chlorine and conventional UV alternatives?
- (2) For which life cycle stages do the results for peracetic acid WWT differ from the base case? What are the differences? Are they significant?
- (3) What is the relationship between differences in impact results for life cycle stages and specified flows of interest?
- (4) What is the effect of plausible parameter variability? What parameters associated with wastewater characteristics have the greatest effect on net greenhouse gas and human health impact results? What parameters associated with uncertainty in treatment system flow rates and concentration-time requirements for chemical-based disinfection or residence time requirements for UV-based disinfection have the greatest effect on net greenhouse gas and human health impact results? How varying estimates of risks does associated with drinking water, containing pathogens and chemicals associated with treated wastewater effluent effect their contribution to total human health results? How does varying estimates of risks associated with exposure through recreational activities and foodcrop irrigation?

2.6.1. Subtask 5.1 - Develop a set of system descriptions for disinfection alternatives

The objective of this subtask is to develop a set of generalized system descriptions representative of operating a municipal WWT system utilizing peracetic acid as the disinfection agent. The system description shall be created in a way in it could replace *disinfection* and other relevant stages within the model developed under Task 4 to represent an alternative full life cycle for wastewater. Together with the system descriptions developed under Task 4, the system descriptions developed within this subtask serve as a framework for the model to be developed in the subtasks, which follow. While *disinfection* is anticipated to be the primary system description effected by the switch to a peracetic acid disinfecting agent, the need to adjust other system descriptions first developed under Task 4 will be considered under this subtask.

The peracetic acid technology will be primarily represented by the subsystems included in the list that follows. In this subtask, the Contractor shall provide additional details underlying the systems listed below and define the reference flows between processes. Each of the processes shall be accompanied by the associated inputs and infrastructure components.

- (1) **Disinfection with peracetic acid, operation** – operation of a WWT system using peracetic acid as a disinfecting agent.
- (2) **Peracetic acid system production** – a reference supply chain representative of a large-scale peracetic acid wastewater disinfection system (the content of this system

diagram may be heavily borrowed from the chlorine disinfection system created in Task 4).

- (3) **Peracetic acid production** – a reference supply chain representative of the processes most likely to be used to produce peracetic acid for use in WWT in the U.S.

For each description the Contractor shall: (a) produce a set of system diagrams and simplified versions of the system diagrams for inclusion in presentations using MS Visio or similar software to be agreed upon with the Work Assignment Manager and (b) write descriptions of: (i) the systems to be analyzed including descriptions of relevant technosphere and natural processes, (ii) the impacts to be tracked and their relevance to the system, (iii) a list of key parameters and initial hypotheses regarding their relative importance for results in key impact categories (i.e., global warming potential), and (iv) the data sources to be used and the transformations necessary to incorporate them into the model. These descriptions serve as a basis for prioritizing and allocating time to data collection and model development activities.

- Milestones:
- (M-5.1.1) **Draft system description** – draft version of the system descriptions in the form of a Microsoft Word file including figures pasted from Visio and associated descriptions for review
 - (M-5.1.2) **Revised system description** – modified version of the system description (M-5.1.1) with all review comments addressed
 - (M-5.1.3) **Revised Visio diagrams** – a zip file containing the diagrams in their original editable format

2.6.2. Subtask 5.2 – Data collection and unit process development

The objective of this subtask is to compile the information needed to develop the LCA model in the subsequent subtasks. To accomplish this, the Contractor shall: (a) collect the necessary data from relevant datasets, literature review, secondary sources, and through coordinating with partners via phone calls and email exchanges; (b) organize a data archive including clearly documented original data and transformations; and (c) process data from its received format into unit process data consistent with use in an LCA model and including relevant metadata. The guidelines for carrying out this subtask are the same as those governing subtask 1.2 and other similar subtasks.

Data for the peracetic acid technology shall be obtained through literature review and through interacting with EPA partner organizations and EPA researchers involved in its development. Wastewater disinfection with peracetic acid is under investigation within EPA's Office of Research and Development and Office of Water. Peracetic acid disinfection is being tested locally within the National Risk Management Research Laboratory (NRMRL) at the lab scale. Results from these studies can be incorporated into this work. In addition, if deemed necessary, additional inputs to the models developed here could be provided through working with NRMRL partners to conduct directed lab tests to clarify Ct required for the standard suit of pathogens being studied (*Cryptosporidium* & *Giardia* oocysts, *Legionella*, adenoviruses and enteroviruses).

The previously developed system descriptions will serve as the basis for unit process development with the goal of establishing a comprehensive model form including parameters governing individual unit processes. Efforts to assign values to parameters and flows will be conducted on an iterative basis with the goal being to establish a base set of values and work from there to improve upon the base set according to the results of model beta runs. The Contractor shall use parameters to govern the inputs and outputs of unit processes to account for a range of values for relevant parameters (see Table 5). During the course of this subtask, the Contractor shall review the system descriptions with the Work Assignment Manager and according to the findings establish an approach to unit process and model development.

To complete this subtask, Contractor shall: (a) produce the necessary additional life cycle inventory unit processes using a template including files in Microsoft Word and Excel format and (b) import unit process data into the openLCA software package.

The requirements and guidance provided in subtask 1.2 regarding provision of data to EPA, documentation format, allocation of time, the use of background datasets apply to this subtask.

- Milestones: (M-5.2.1) **Draft Unit Processes** – a zip file or similar containing unit processes used in this Statement of Work provided for review. Unit processes shall be provided in the form of MS Word and Excel files as described above.
- (M-5.2.2) **Electronic data collection archive** – a zip file or similar containing the results of data collection in the form of PDF and other files organized in labeled folders
- Deliverables: (D-5.2.1) **Unit Processes (revised)** – a zip file or similar containing modified versions of the draft unit processes (M-5.2.1) following incorporation of review comments

2.6.3. Subtask 5.3 – Collect and process economic data for municipal-scale disinfection alternatives

The objective of this subtask is to augment the account of the economic structure of WWT developed in Task 4 to represent the alternative system using peracetic acid. The product of this work will be a series of spreadsheets describing the infrastructure, operation, and maintenance costs for drinking water systems utilizing the peracetic acid treatment technology. This account shall be consistent with and directly build upon the economic accounts developed under Task 4. The Contractor shall collect the additional cost information associated with processes representative of peracetic acid wastewater disinfection and integrate them with the appropriate portions of the base case WWT spreadsheet accounts. Cost data will be collected from project partners using a format similar to the one developed under the preceding Tasks. This shall be supplemented with data from the literature where necessary. The electronic files associated with data collection and literature search shall be organized and saved in an electronic archive to be provided to EPA for future reference. All data collected shall be provided to EPA and disseminated publicly by EPA at its discretion.

- Milestones: (M-5.3.1) **Draft economic account** – a series of spreadsheets containing accounts for infrastructure components, construction processes,

operation and maintenance processes, and key infrastructure requirements associated with maintenance. Unit processes shall be provided in the form of Excel files with accompanying documentation.

(M-5.3.2) **Electronic data collection archive** – a zip file or similar containing the results of data collection in the form of PDF and other files organized in labeled folders

Deliverables: (D-5.3.1) **Economic account (revised)** – a zip file or similar containing modified versions of the economic account (M-5.3.1) following incorporation of review comments

2.6.4. *Subtask 5.4 – Incorporate unit processes and perform the reference LCA model run for peracetic acid disinfection*

The objectives of this subtask are (1) to ensure the unit processes are properly incorporated into the LCA model and then (2) to use the model to generate results for the a reference set of model runs for disinfection alternatives to address the questions posed in the first section of the task description and additional questions identified in the course of the work as agreed upon with the EPA Work Assignment Manager. As in previous tasks, the LCA model shall be: (a) developed within an appropriate LCA software platform which allows for full conversion to the open LCA software platform by EPA, (b) based on transparent, public or commercially-available background data, and (c) submitted to EPA for quality assurance and review of unit process data at appropriate points in the project timeline to allow for the Contractor to incorporate EPA-provided comments/revisions.

Only a single model run is anticipated for the peracetic acid WWT case. Additional sensitivity analysis runs are presented on the right side of Table 5 and described in the subsequent subtask.

Following a review of preliminary results by the EPA Work Assignment Manager, the results shall be documented in tabular form in an Excel or similar spreadsheet file. This documentation shall include sufficient commenting to identify the systems and parameters represented by each run and shall include a breakdown of results by impact and WWT process/life cycle stage.

Milestones: (M-5.4.2) **Results for reference set of model runs for disinfection alternatives** – tabular results for the model runs provided electronically in an Excel or similar file

Deliverables: (D-5.4.1) **Updated life cycle inventory database** - a file exported from the LCA software such as a GaBi exchange file (or standard LCA data exchange format such as ILCD or Ecospol) and provided electronically

2.6.5. *Subtask 5.5 - Sensitivity analysis and optional additional uncertainty analysis*

The Contractor shall conduct a sensitivity analysis to understand the effect of variability in key parameters on the results of the LCA model. Key parameters shall be identified in consultation with the EPA Work Assignment Manager. The effect of variability shall be assessed parametrically and the results presented in the form of appropriate tables or figures. To provide a clear basis for estimating the level of effort required, a set of model runs anticipated to be evaluated is provided in the columns on the right of Table 5. The sensitivity analysis conducted

under this subtask shall be conducted in a way, which is consistent with the approach used in the preceding Tasks.

If during the course of carrying out this Task it is determined that modifications to the model runs represented in Table 5 are warranted, these modifications shall be made in such a way the overall level of effort required to carry out this Task is not effected.

Milestones: (M-5.5.1) **Sensitivity analysis results for disinfection alternatives** – tabular results for the sensitivity analysis model runs provided electronically in an Excel or similar file

2.6.6. Subtask 5.6 – Integration and representation of results

The objective of this subtask is to develop a set of intuitive, well-edited figures presenting a set of key results from the base case and disinfection alternative model runs and economic accounts appropriate for engaging decision-makers. This subtask involves the integration of results for both the base case and disinfection alternatives to compare technologies and highlight key system aspects. To accomplish this subtask, the Contractor shall engage in discussion with the EPA Work Assignment Manager, select key results and sources of variability to be presented based on the discussion, formulate an appropriate means of conveying key information, develop a draft set of figures for EPA review, and revise figures according to review comments received from the Work Assignment Manager. This work will involve performing additional spreadsheet calculations and data manipulations to combine economic and life cycle impact results for both the base case and disinfection alternative systems and to draw out important features of the data. The final set of results shall reflect key aspects of the analysis, which will be expanded on in the discussion provided in the manuscript produced within the subsequent subtask.

Milestones: (M-5.6.1) **Draft key figures for comparison of base case and disinfection alternatives** – key figures provided electronically in an Excel or similar file for review

Deliverables: (D-5.6.2) **Key figures for comparison of base case and disinfection alternatives (revised)** – revised version of the draft key figures (M-5.6.1) modified in response to comments

2.6.7. Subtask 5.7 – Documentation and manuscript writing: model development and LCA results for comparison of base case and alternative disinfection technologies

The objective of this subtask is to document the model and results produced in this Task in a manuscript and associated supporting information in a format appropriate for submission to a scientific journal. To accomplish this, the Contractor shall: (a) write sections of a manuscript presenting model development and LCA and economic results for comparison of base case and alternative disinfection technologies, (b) respond to comments provided through an internal peer-review process coordinated by the EPA Work Assignment Manager, (c) prepare and format materials in accordance with the specifications for the journal agreed upon through discussion with the EPA Work Assignment Manager, and (d) assist EPA in responding to comments received from the journal peer-reviewers in coordination with the EPA Work Assignment

Manager. It is anticipated the EPA Work Assignment Manager and/or (a) member(s) of the EPA Technical Team will provide significant input to the manuscript and serve as (a) co-author(s).

This manuscript shall contain at minimum the following sections: abstract, literature review, method, results, sensitivity analysis, and discussion and shall be accompanied by a document containing supporting information (SI). The abstract shall highlight key points from the article focusing on key quantitative insights. The literature review shall provide context for the work performed within the preceding subtasks including presenting key findings from previous studies, placing this study within the context of prior studies, and describing previous studies and data collection efforts, which were utilized in the development of the LCA model developed within this Statement of Work. The method shall include the system diagrams developed in Task 1, descriptions of the unit processes that make up the systems, a brief description of the impact assessment methods used in the model (or reference to previous manuscript), a brief description of the economic accounts and data sources, and references to more detailed information provided in the supporting information (SI). The results shall include selected figures developed in Subtask 5.6 as well as reference to more detailed results provided in the SI. Similarly, the sensitivity analysis shall provide a description of the sensitivity analysis, selected figures associated with the sensitivity analysis, and references to more detailed sensitivity results provided in the SI. The discussion shall address the interpretation of results, strengths, and limitations of the results and approach, implications of results for decision-making, and next steps for further investigation of questions that arise in the course of this work. The SI shall include more detailed quantitative information necessary for understanding the model, other results produced in this Task not included in the main manuscript, and text documenting the supporting information.

- Milestones: (M-5.7.1) **Draft Task 5 manuscript**– draft version of the manuscript for project internal peer-review
- (M-5.7.2) **Response to peer-review of Task 5 manuscript** – including a revised version of the submitted manuscript (D-5.7.1) modified to address comments received through external peer-review and a Word file containing itemized responses to reviewer comments
- Deliverables: (D-5.7.1) **Task 5 manuscript: Model Development and LCA Results for Drinking Water Treatment Options (revised and formatted)** – revised version of the draft manuscript (M-5.7.1) formatted for submission to an appropriate peer-reviewed, scientific journal

3. PREPARATION OF A QUALITY ASSURANCE PROJECT PLAN

Performance under this task order requires the contractor to prepare a Quality Assurance Project Plan (QAPP) to be included as part of Task 1. The contractor shall submit a QAPP with its proposal in accordance with EPA Requirements for Quality Assurance Project Plans found here: <http://www.epa.gov/QUALITY/qs-docs/r5-final.pdf>. The QAPP shall be submitted to EPA for internal review within three weeks of project commencement and approval and the Contractor shall revise the QAPP to fully address the EPA review comments. The Task Order Work Assignment Manager and Quality Assurance Manager must approve the contractor's QAPP before Task Order award. Following approval of the QAPP, the contractor shall perform all tasks under the Task Order in accordance with the quality standards established in the QAPP. The requirements for a Secondary Data Project QAPP are provided in an Appendix.

Milestones: (M-0.0.1) **Draft QAPP** – a draft version of the QAPP for EPA QA Manager and Work Assignment Manager review within three weeks of project commencement

Deliverables: (D-0.0.1) **QAPP (revised)** – a revised version of the QAPP (M-0.0.1) with all review comments addressed

4. TASK MANAGEMENT

During the course of this Task, the Contractor shall initiate weekly communication by telephone conversation and electronic correspondence with the EPA Work Assignment Manager to discuss progress. While communication can be conducted through e-mail, it is anticipated that well-planned and efficient teleconferences will be used as the primary means of communication. In addition, WAMs will send any Technical Direction in writing via email within five days of verbal communication.

The Contractor shall notify the CO and EPA WAM in writing to indicate the points at which 25%, 50%, 75%, and 90% of the authorized work assignment LOE/labor hours have been expended.

5. SCHEDULE AND REQUIRED DELIVERABLES

The following list describes the deliverables associated with the successful execution of the tasks. This list is subject to modification per notification from the EPA Work Assignment Manager. A Quality Assurance Project Plan (QAPP) is required prior to beginning work. The QAPP shall be revised to address EPA QA Manager findings and approved by the EPA QA Manager prior to beginning data collection efforts. Deliverables required for Task 1 shall be delivered 6 months after the Contract award date. The exact timing of other deliverables shall be determined following an exchange between the Contractor and the Work Assignment Manager and notification provided by the EPA Work Assignment Manager.

ID	Deliverable
(D-0.0.1)	Quality Assurance Project Plan – delivered prior to continuing Task 1

(D-1.2.1)	Unit processes for base case drinking water treatment – 6 months after award
(D-1.3.1)	Economic account for base case drinking water treatment – 6 months after award
(D-1.4.1)	Life cycle inventory database base case drinking water treatment – 6 months after award
(D-1.6.2)	Key figures for the base case – 6 months after award
(D-1.7.1)	Task 1 manuscript: Model Development and LCA Results for Drinking Water Treatment Options – 6 months after award
(D-2.2.1)	Unit processes for drinking water treatment alternatives
(D-2.3.1)	Economic account updated with alternative DWT technologies
(D-2.4.1)	Life cycle inventory database updated with alternative DWT technologies
(D-2.6.2)	Key figures for comparison of base case and disinfection alternatives
(D-2.7.1)	Task 2 manuscript: Model Development and LCA Results for Drinking Water Treatment Options
(D-3.2.1)	Unit processes for point-of-use treatment options
(D-3.3.1)	Economic account updated with point-of-use treatment options
(D-3.4.1)	Life cycle inventory database updated with point-of-use treatment options
(D-3.6.2)	Key figures for comparison of point-of-use options
(D-3.7.1)	Task 3 manuscript: Model development and LCA results for point-of-use drinking water treatment options
(D-4.2.1)	Unit processes for base case wastewater treatment
(D-4.3.1)	Economic account for base case wastewater treatment
(D-4.4.1)	Life cycle inventory database updated with base case wastewater treatment
(D-4.6.2)	Key figures for the base case wastewater treatment
(D-4.7.1)	Task 4 manuscript: Model Development and LCA Results for Drinking Water Treatment Options
(D-5.2.1)	Unit Processes for peracetic acid wastewater treatment
(D-5.3.1)	Economic account for peracetic acid wastewater treatment
(D-5.4.1)	Life cycle inventory database updated with peracetic acid wastewater treatment
(D-5.6.2)	Key figures for comparison of wastewater treatment base case and peracetic acid alternative
(D-5.7.1)	Task 5 manuscript: Model Development and LCA Results for Drinking Water Treatment Options

6. CONTRACT PERFORMANCE WORK STATEMENT REFERENCE

Section 3.0 of the Performance Work Statement of Contract EP-C-12-021.

7. ANTICIPATED TRAVEL REQUIREMENTS

No Contractor travel is anticipated under the Scope of this work.

8. ADDITIONAL REQUIREMENTS

Office direct costs (ODCs) for copying, postage/courier, supplies, computer usage, and graphics are allowed. No other ODCs are allowable as a direct charge to this work assignment without the prior written approval of the Contracting Officer.

Upon issuance of written technical direction, the Contractor shall submit for inspection of all work in progress at any time under this work assignment. The Contractor shall develop and maintain files supporting each task.

The contractor shall contact the Contracting Officer (CO) and/or the Project Officer (PO) by telephone to discuss any problems that may adversely affect the work on this Work Assignment. Within five (5) calendar days the contractor shall follow the phone call with a brief written explanation of the problem, including any actions already taken, and/or recommended solutions to correct the problem. Written explanation shall be made available to the CO and the PO.

9. CONTRACTOR IDENTIFICATION

To avoid any perception that contractor personnel are EPA employees, the contractor shall assure that contractor personnel are clearly identified as independent contractors of EPA when attending meetings with outside parties or visiting field sites.

10. QUALITY CONTROL REQUIREMENTS

1. Quality Assurance (QA) Project Plan:

This Quality Assurance (QA) Project Plan describes how the Office of Water will comply with EPA's quality system requirements set forth in EPA Order 5360.1. The purpose of the QA Plan is to provide a blueprint for planning, implementing, and assessing the quality system for the programs administered by the Office of Water.

It is the policy of OW that QA activities shall be conducted to assure environmental data generated, processed or used for its program requirements will be of known quality, and will achieve prescribed data quality objectives. Furthermore, the data will be adequate and sufficient for their intended use.

For each Statement of Work that generates or analyzes environmental data, the contractor shall include:

- a description of how the data will be generated by the contractor
- a requirement that the contractor prepare a QA Plan
- for data from EPA databases this should include the report, documentation of select logic, and pull/refresh dates
- for data from other sources (e.g., Websites, publications) appropriate source information shall also be maintained.

The contractor is responsible for preparing a QA Project Plan in accordance with the guidance document EPA Requirements for Quality Assurance Project Plans; EPA QAIG-5, December 2002.

2A. Organizational Conflict of Interest:

The Contractor shall warrant that, to the best of the Contractor's knowledge and belief, there are no relevant facts or circumstances which could give rise to an organizational conflict of interest, as defined in FAR Subpart 9.5, or that the contractor has disclosed all such relevant information. See contract clause 1552.209-71 Organization of Conflict of Interest.

2B. Notification of Conflicts of Interest Regarding Personnel:

The Contractor shall immediately notify the Project Officer and the Contracting Officer of (1) any actual or potential personal conflict of interest with regard to any of its employees working on or having access to information regarding this contract, or (2) any such conflicts concerning subcontractor employees or consultants working on or having access to information regarding the contract, when such conflicts have been reported to the Contractor. A personal conflict of interest is defined as a relationship of an employee, subcontractor employee, or consultant with an entity that may impair the objectivity of the employee, subcontractor employee, or consultant in performing the contract work. See Section H.4, contract clause EPAAR 1552.209-73 Notification of Conflict of Interest.

3. Project Employee Confidentiality Agreement

The contractor agrees that the contractor employee will not disclose, either in whole or in part, to any entity external to the EPA, the Department of Justice, or the contractor, any information or data (as defined in FAR Section 27.401) provided by the government or first generated by the contractor under this contract, any site-specific cost information, or any enforcement strategy without first obtaining the written permission of the EPA Project Officer. If a contractor, through an employee or otherwise, is subpoenaed to testify or produce documents, which could result in such disclosure, the contractor must provide immediate advance notification to the EPA so that the EPA can take action to prevent such disclosure. Such agreements shall be effective for the life and for a period of five (5) years after completion of the contract.

4. Handling of Confidential Business Information (CBI)

Contractor's access to TSCA CBI must comply with the procedures set forth in the TSCA CBI Security Manual. Likewise, access to FIFRA CBI shall follow the security procedures set forth in the FIFRA Information Security Manual.

To the extent that the work under this contract requires access to proprietary or confidential business or financial data of other companies, and as long as such data remains proprietary or confidential, the contractor shall protect such data from unauthorized use and disclosure.

All files or other information identified as Confidential Business Information (CBI) shall be treated as confidential and kept in a secure area with access limited to only contractor personnel directly involved in the case or special project assignment. The contractor, subcontractor, and consultant personnel are bound by the requirements and sanctions contained in their contracts with the EPA and in EPA's confidentiality regulations found at 40 CFR Part 2, Subpart B. The contractor subcontractors, and consultant must adhere to EPA-approved security plans which describe procedures to protect CBI, and are required to sign non-disclosure agreements before gaining access to CBI.

All official data, findings, and results of investigations and studies completed by the contractor shall be available for EPA and DOJ internal use only. The contractor shall not release any part of such data without the written direction of the WAM.

APPENDIX I: RELATED REFERENCES

APPENDIX II: QUALITY ASSURANCE PROJECT PLAN REQUIREMENTS*Revision 0 10/2008***NRMRL QAPP REQUIREMENTS FOR SECONDARY DATA PROJECTS**

GENERAL REQUIREMENTS: Include cover page, distribution list, approvals, and page numbers.

0. COVER PAGE

Include the Division/Branch, project title, revision number, EPA technical lead, QA category, organization responsible for QAPP preparation, and date.

1. PROJECT DESCRIPTION AND OBJECTIVES

- 1.1 Describe the process and/or environmental system to be evaluated.*
- 1.2 State the purpose of the project and list specific project objective(s).*

2. ORGANIZATION AND RESPONSIBILITIES

- 2.1 Identify all project personnel, including QA, and related responsibilities for each participating organization, as well as their relationship to other project participants.*
- 2.2 Include a project schedule that includes key milestones.*

3. SCIENTIFIC APPROACH

- 3.1 Identify the secondary data needed to meet the project objective(s). Specify requirements relating to the type of data, the age of data, geographical representation, temporal representation, and technological representation, as applicable.*
- 3.2 Identify the source(s) for the secondary data. Discuss the rationale for selecting the source(s) identified. If a hierarchy of sources exists for the gathering of secondary data, specify that hierarchy.*

4. QUALITY METRICS

- 4.1 Specify the quality requirements of the secondary data. These requirements must be appropriate for the intended use of the data. Address accuracy, precision, representativeness, completeness, and comparability, if applicable.*
- 4.2 Describe the procedures for determining the quality of the secondary data.*
- 4.3 If no project-specific data quality requirements exist, state this in the QAPP. If the quality of the secondary data will not be evaluated by EPA, require that a disclaimer be added to any project deliverable to indicate the quality of the secondary data has not been evaluated by EPA for this specific application. Provide the wording for the disclaimer.*

5. DATA ANALYSIS, INTERPRETATION, AND MANAGEMENT

- 5.1 Identify the data reporting requirements, including data reduction procedures specific to the project and applicable calculations and equations.*
- 5.2 Describe data validation procedures used to ensure the reporting of accurate project data.*
- 5.3 Describe how the data will be summarized or analyzed (e.g., qualitative analysis, descriptive or inferential statistics) to meet the project objective(s).*

- 5.3.1 *If descriptive statistics are proposed, state what tables, plots, and/or statistics (e.g., mean, median, standard error, minimum and maximum values) will be used to summarize the data.*
- 5.3.2 *If an inferential method is proposed, indicate whether the method will be a hypothesis test, confidence interval, or confidence limit and describe how the method will be performed.*
- 5.4 *Describe data storage requirements for both hard copy and electronic data.*

6. REPORTING

- 6.1 *List and describe the deliverables expected from each project participant.*
- 6.2 *Specify the expected final product(s) that will be prepared for the project (e.g., journal article, final report, etc.). Specify the source(s) of the secondary data in any deliverable.*

REFERENCES

Provide references either in the body of the text as footnotes or in a separate section.

APPENDIX III: STANDARD OPERATING PROCEDURE FOR LIFE CYCLE ASSESSMENT

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**UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY**



ORD/NRMRL/Sustainable Technology Division/SAB

STD Site Specific Work Instruction (SOP)

SOP No. S-11786-OP-1-0

Life Cycle Assessment Projects Involving Inventory Data Collection

ORIGINATED BY: **Wesley Ingwersen, ingwersen.wesley@epa.gov, 513-569-7602**

Date: **10 August 2012**

REVIEWED BY: **Daniel Young, STD QAM**

Date: **10 August 2012**

APPROVED BY: **Matthew Hopton**

Date:

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Scope

This Standard Operating Procedure (SOP) applies to Life Cycle Assessment (LCA) projects involving data collection managed by ORD principal investigators (PIs) that involve the ORD LCA database, including projects in which contractors to the Agency are collecting data.

Purpose

The purpose of this SOP is (1) to assure consistency and accuracy in data collection and impact assessment for LCA projects within ORD, (2) to assure that data collected in ORD LCA projects gets added to a common, accessible database for use in future LCA projects, (3) to assure that all ORD-generated LCA data is well documented, and (4) to describe relevant quality control procedures.

Terms

Ecospold – A data format designed by the Ecoinvent Centre for the exchange of LCA datasets [Ecoinvent Centre 2012]

Life cycle assessment (LCA) – Compilation and evaluation of the inputs, outputs, and potential environmental impacts of a product system throughout its life cycle [ISO 14044:2006]

Life cycle inventory database (LCA database) – A system intended to organize, store, and retrieve large amounts of digital life cycle inventory datasets easily. It consists of an organized collection of LCI datasets that completely or partially conforms to a common set of criteria, including methodology, format, review, and nomenclature, and that allows for interconnection of individual datasets that can be specified for use with identified impact assessment methods in application of life cycle assessments and life cycle impact assessments. [UNEP-SETAC 2011]

OpenLCA – A modular open-source software for life cycle analysis and sustainability assessment [Greendelta 2012]

Unit process – Smallest element considered in the life cycle inventory analysis for which input and output data are quantified. [ISO 14044:2006]

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LCA Help and Standards Documents

Links to key references to public documents relevant for developing LCA models can be found on the LCA and LCA Resources webpages:

<http://www.epa.gov/nrmrl/std/lca/lca.html>

<http://www.epa.gov/nrmrl/std/lca/resources.html>

Copies of relevant LCA guidance documents purchased by STD are available via request.

The ORD LCA Database

The ORD LCA database houses ORD project life cycle inventory data as well as well as life cycle inventory datasets from proprietary and non-proprietary sources. The database is in the standard format used in the OpenLCA software.

Proprietary Data Currently Maintained within the Restricted Access Portion of the ORD LCA Database:

GaBi version 4 (2011) databases:

GaBi 4 professional

Extension database Ib: Inorganic intermediates

Extension database II: Energy

Extension database IX: End of life

Extension database XII Renewable raw materials

Extension database XVII: US database

Ecoinvent 2.2 (2009) and 3.0 (expected October 2012)

NETL Corn Ethanol and Gasoline Data (2010)

NREL Biofuels Data (2010)

Procedure

Before initiating a new LCA project involving data collection, the principal investigator should contact an STD LCA expert to share the intended project plan. The collaborating STD LCA Expert will help to determine if this SOP should apply to the project.

If it is agreed that this SOP is applicable, the following procedure applies:

File transfer

The STD LCA Expert will provide the PI and team members with the following files:

1. A copy of the most recent version of the ORD LCA database. The database will contain all datasets generated through ORD projects as well as proprietary datasets (e.g. Ecoinvent, GaBi) for which the PI and team have a license
2. The LCA unit process data template (in MS Excel and optionally, MS Word, formats)
3. A list of elementary flow names present in the database
4. The Ecospol Access plugin installation files

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Installation of OpenLCA and Ecospold plugin

The PI and those intending to work with the database should install the following software on their workstations:

1. OpenLCA software (version recommended by the STD LCA Expert)
2. The Ecospold Access plugin (most recent version)

The STD LCA Expert will provide the PI and team with an instructional tutorial on using the ORD LCA database, unit process template, and associated files and plugins.

Prior to proceeding with entry of data into the unit process template, the PI must prepare and have approved a QAPP that includes procedures for maintaining unit process data quality as well as for assuring model integrity in OpenLCA.

Unit process template

All original unit processes shall be created using the LCA unit process template. The template can be used for documenting and generating Ecospold files for one process or more than one process if these processes are based on data, inputs, and outputs of similar structure. Processes may have more than one product, but all inputs and outputs will be in reference to a specified quantity of one product (the reference flow). The template consists of worksheets for entry of general information about the processes described ('Info' and 'Data Summary'), for input-output data ('Input-Output'), for references ('Reference Source Info'). These worksheets shall all be completed. Use of the 'DQI', 'Calculations', 'Conversions', 'TransportReqs' and 'Parameters' sheets can be used to documents data quality, calculations, estimate transportation requirements, and use parameters, and should be used when applicable. The Ecospold worksheets (all that start with an 'X-') will automatically be filled with data from the other sheets and only need to be error-checked and then corrected when data are not passed correctly from the other sheets.

Adding inputs and outputs from the flow list/database or creating new flows

Flow names, location, and unit types (e.g., mass) must all match existing flows in the ORD LCA database. For elementary flows, please refer to the list of elementary flow names provided. For product flows, if the product is an existing product in the database, you must find the exact name, location, and unit type corresponding to that product in the ORD LCA database. This can be done by searching through the database processes using the search tool in OpenLCA. If the product flow name does not exist in the database, you must create an additional unit process that provides that product as an output. If a flow name does not exist in the flow list, it will be added to the database upon import of the process. Note that flows WILL NOT be matched with characterization factors unless you make these edits manually to the relevant LCIA method file in OpenLCA. If edits are made these must be submitted separately with submission of the project data.

Creating Ecospold files

Once unit process templates are complete and all information is being correctly passed to the Ecospold worksheets, an Ecospold XML file should be generated using the Ecospold access plugin. Critical errors will prevent the creation of an Ecospold file and should be identified and corrected. The plugin will validate the Ecospold file against the Ecospold XML Schema. Once the Ecospold file is exported, it will be ready for import into OpenLCA.

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Checking processes in OpenLCA

Once a process is successfully imported into open LCA, the process should be reviewed to assure all inputs and outputs, quantities, units, and metadata were correctly imported. For each unique process (or one of a set of multi-processes if those processes have the same set of inputs and outputs), a product system should be created based on that process without upstream connections. A “result” and then “analysis” should be calculated for the product system using the LCIA method intended to be used in the study. The analysis should be reviewed to assure that each elementary flow is characterized under each impact category for which a characterization factor is available for the flow of interest. Note this method of checking that flows from select processes are characterized can be superseded if a more efficient method is developed.

Checking supply chains in OpenLCA

For the final product, or for designated substages of a supply chain for complex supply chains where responsibilities were distributed amongst a team, a product system should be created with connected processes. The product system diagram should be inspected upstream for ALL inputs to until a connection to a validated background database is reached to assure that connections are in place and are to the correct process.

Results and analysis should be conducted. A reasonableness check should be conducted for each impact category by reviewing the ‘Contribution to characterization’ table and/or the ‘Sankey diagrams’. All unreasonably large contributions or unexpectedly small contributing processes should be noted and then investigated more closely until the analysis is determined correct, or the error is detected and is resolved.

Submitting data back to the ORD LCA database

The ORD project PI should submit all completed unit processes in the Excel templates and Ecospolld form to QA review. Once processes have passed QA, the ORD PI should forward these documents and any related materials to the STD LCA Expert. The STD LCA Expert will review the processes and incorporate them into the ORD LCA database. If STD LCA Expert identifies problems preventing the incorporation of the data, the ORD PI must work with the LCA Expert to address these problems before the data can be integrated. A revised copy of the ORD LCA database will then be made available to the PI as well as the ORD LCA community.

Storage Location and Backup of the ORD LCA database and Associated Files

All metadata associated with unit processes archived in the ORD LCA database will be saved and backed up on EPA’s network at the following location:

L:\Public\NRMRL-PUB\STD\LCA\STD LCA Database\

A copy of the master ORD LCA database with non-proprietary data will be maintained in the form of an openLCA database file (.olca) on the network in a folder under the same location. A copy of the master ORD LCA database with all data will be maintaining in a secure network location.

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Notes

The ORD LCA database is maintained and managed by the STD LCA Experts.

References

GreenDelta (2012). The openLCA project. <http://www.openlca.org/>

Ecoinvent Centre (2012) Ecospold Data Format. Swiss Centre for Life Cycle Inventories, Dübendorf, CH. <http://www.ecoinvent.org/database/ecospold-data-format/>.

ISO (2006) 14044: Environmental management -- Life cycle assessment -- Requirements and guidelines. International Standards Organization, Geneva.

UNEP/SETAC Life Cycle Initiative (2011) Global Guidance Principles for Life Cycle Assessment Databases (Shonan Guidance Principles).

APPENDIX IV: LIFE CYCLE INVENTORY UNIT PROCESS DOCUMENTATION (WORD DOCUMENT)

The following pages contain the Microsoft Word template for use in documenting unit process data used in the LCA model. The accompanying Excel file can be provided upon request.



Life Cycle Inventory

Unit Process Documentation

Process Name: <enter process name - 50 character limit>
Reference Flow: <enter value, units, and reference flow name>
Brief Description:

Section I: Meta Data

Region:	US	State:	<name>
Year Best Represented:	yyyy	County:	<county>
Category:	<Category>	Geographic comment:	<No comments.>
Subcategory:	<Subcategory>		
Process Scope:	<select from list>		
Allocation Applied:	<select from list>	Latitude:	<latitude>
Completeness:	<select from list>	Longitude:	<longitude>

Relevant Input Flows Included in Data Set:

Elementary inputs: ☐ Minerals ☐ Energy ☐ Water ☐ Other
Technosphere inputs: ☐ Materials ☐ Energy ☐ Transportation
☐ Services ☐ Other

Relevant Output Flows Included in Data Set:

Releases to Air: ☐ Greenhouse Gases ☐ Criteria Air Pollutants ☐ Other
Releases to Water: ☐ Inorganic Emissions ☐ Organic Emissions ☐ Other
Water Usage: ☐ Water Input ☐ Water Returned to Environment
Releases to Soil: ☐ Inorganic Releases ☐ Organic Releases ☐ Other

Adjustable Process Parameters:

First parameter name	<i>First parameter description</i>
Second parameter name	<i>Second parameter description</i>



Life Cycle Inventory

Unit Process Documentation

Tracked Input Flows:

First input flow name [category name]	<i>Input flow description</i>
Second input flow name [category name]	<i>Input flow description</i>
...	...

Tracked Output Flows:

Reference flow name [category name]	<i>Output flow description</i>
Other co-product flow name if applicable [category name]	<i>Output flow description</i>
...	...

Section II: Process Description

Associated Documentation

Add text.

Goal and Scope

Add text.

Boundary and Description

Add text.

Figure 1: Unit Process Scope and Boundary

Table 1: Properties for <Process name>

Data Description	Value	Unit	Source

Table 2: Unit Process Input and Output Flows

Flow Name*	Value	Units (Per Reference Flow)
Inputs		
Outputs		

* **Bold face** clarifies the value shown *does not* include upstream environmental flows. See the documentation for embedded unit processes, as shown below.

References

Add text.

Section III: Document Control Information

Date Created: July 19, 2011

Point of Contact: Your name and email address here. List other co-authors here as well.

Revision History:

Add text, for example: Original/no revisions

Reference information:

<Last name, First name, etc.> (2011). Life Cycle Inventory Unit Process Documentation: <Process Name>. U.S. Environmental Protection Agency, National Risk Management Research Laboratory. Version: <insert version, e.g. 0.1>, Last updated: <insert date>

Section IV: Disclaimer

Neither the U.S. Environmental Protection Agency nor any person acting on behalf of this organization:

- A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this document, or the use of any information, apparatus, method, or process disclosed in this document may not infringe on privately owned rights; or
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Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by EPA. The views and opinions of the authors expressed herein do not necessarily state or reflect those of EPA.

Work Assignment Form, (WebForms v1.0)

EPA United States Environmental Protection Agency Washington, DC 20460 Work Assignment						Work Assignment Number 0-41				
						<input type="checkbox"/> Other <input checked="" type="checkbox"/> Amendment Number: 000001				
Contract Number EP-C-12-021			Contract Period 09/26/2012 To 09/25/2013 Base <input checked="" type="checkbox"/> Option Period Number			Title of Work Assignment/SF Site Name Systems-Based Sustainability				
Contractor EASTERN RESEARCH GROUP, INC.					Specify Section and paragraph of Contract SOW N/A					
Purpose: <input type="checkbox"/> Work Assignment <input type="checkbox"/> Work Assignment Close-Out <input checked="" type="checkbox"/> Work Assignment Amendment <input type="checkbox"/> Incremental Funding <input type="checkbox"/> Work Plan Approval						Period of Performance From 12/19/2012 To 09/25/2013				
Comments: The purpose of this Amendment 1 is to change the WAM from Debbie Flanigan to Troy Hawkins, Phone: 513-569-7139, E-mail: hawkins.troy@epa.gov.										
<input type="checkbox"/> Superfund Accounting and Appropriations Data <input checked="" type="checkbox"/> Non-Superfund										
Note: To report additional accounting and appropriations data use EPA Form 1900-69A.										
SFO (Max 2) <input type="checkbox"/>										
Line	DCN (Max 6)	Budget/FY (Max 4)	Appropriation Code (Max 6)	Budget Org/Code (Max 7)	Program Element (Max 9)	Object Class (Max 4)	Amount (Dollars)	(Cents)	Site/Project (Max 8)	Cost Org/Code (Max 7)
1										
2										
3										
4										
5										
Authorized Work Assignment Ceiling										
Contract Period:		Cost/Fee:			LOE:					
09/26/2012 To 09/25/2013										
This Action:										
Total:										
Work Plan / Cost Estimate Approvals										
Contractor WP Dated:				Cost/Fee:			LOE:			
Cumulative Approved:				Cost/Fee:			LOE:			
Work Assignment Manager Name Troy Hawkins <div style="display: flex; justify-content: space-between;"> <div>_____ (Signature)</div> <div>_____ (Date)</div> </div>							Branch/Mail Code: Phone Number 513-569-7139 FAX Number:			
Project Officer Name Meghan Hessenauer <div style="display: flex; justify-content: space-between;"> <div>_____ (Signature)</div> <div>_____ (Date)</div> </div>							Branch/Mail Code: Phone Number: 202-566-1040 FAX Number:			
Other Agency Official Name <div style="display: flex; justify-content: space-between;"> <div>_____ (Signature)</div> <div>_____ (Date)</div> </div>							Branch/Mail Code: Phone Number: FAX Number:			
Contracting Official Name Brad Heath <div style="display: flex; justify-content: space-between;"> <div>_____ (Signature)</div> <div>_____ (Date)</div> </div>							Branch/Mail Code: Phone Number: 513-487-2352 FAX Number:			